WRANGELL - ST. ELIAS NATIONAL PARK AND PRESERVE,

ALASKA

WATER RESOURCES SCOPING REPORT

Don P. Weeks

Technical Report NPS/NRWRD/NRTR-2003/315

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
Fort Collins - Denver - Washington

United States Department of the Interior • National Park Service

The National Park Service Water Resources Division is responsible for providing water resources management policy and guidelines, planning, technical assistance, training, and operational support to units of the National Park System. Program areas include water rights, water resources planning, regulatory guidance and review, hydrology, water quality, watershed management, watershed studies, and aquatic ecology.

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Technical Report NPS/NRWRD/NRTR-2003/213

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United States Department of the Interior
National Park Service

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EXECUTIVE SUMMARY

Water Resource Scoping Reports (WRSRs) provide National Park Service (NPS) management with a better understanding of a park's water resources and the current issues it faces. These reports typically summarize existing hydrological information, identify and analyze major water resource issues, and determine if further development of the water-related issues, including recommended actions (project statements) that address the high-priority issues, is warranted through a Phase II process that builds from the scoping report. In certain cases, WRSRs meet the current water management needs for park units, where the number and complexity of issues are minimal.

For Wrangell - St. Elias National Park and Preserve (WRST), the water-related issues are numerous, time sensitive, and complex; thus, the need for the more comprehensive second phase process is warranted. The primary objective of this report is to; 1) provide background for WRST's natural resources and relevant water-related legislation, 2) identify the major water-related issues, and 3) present information relevant to these issues, including management considerations that will serve as the foundation for the Phase II effort.

WRST is our largest NPS unit at 13.2 million acres, where the Chugach, Wrangell, and St. Elias mountain ranges converge, producing the continent's largest assemblage of glaciers and the greatest collection of peaks above 16,000 feet, spawning the numerous fluvial systems at lower elevations. The park and preserve's water resources are diverse and extensive, including wetlands, glaciers, icefields, marine coast, ground water, thermal springs, lakes, and large river systems.

The contents of this report are limited to information made available to the author during the time this report was prepared. Where appropriate, issue-specific recommendation(s) previously proposed by NPS management via WRST planning documents (i.e., GMP, RMP) are included. As a result, descriptions of the natural resources and water resource issues vary in detail, and inclusion of issue-related recommendations is inconsistent.

As part of the effort by the NPS Water Resources Division (WRD) to produce this report, WRD staff traveled to the park/preserve in 2002. The purposes of this travel were to: 1) introduce elements of the WRSR effort to WRST, 2) become familiar with the water resources and high priority water-related issues at the park, and 3) obtain pertinent information from park files, Alaska Resources Library and Information Services (ARLIS) and the U.S. Geological Survey. The priority issues identified at WRST during this effort and discussed in this report include:

- <u>*Baseline Inventory and Monitoring*</u> - An inventory of water resources is needed at WRST. WRST staff should continue to provide existing water quality data to the NPS Water Resources Division for inclusion in WRST's *Baseline Water Quality and Inventory and Analysis* report. GIS water quality data layers that identify sampling sites in the park and preserve and cross-reference these sites with their water quality databases are needed. River gaging stations installed within close proximity to WRST's major glaciers are needed to evaluate glacial influences on stream flows, while integrating the data in studies of glacier snow, ice and water balance. WRST should continue to work with the Central Alaska Inventory and Monitoring Network to design and implement a regional water quality monitoring program. Sampling efforts in WRST by the NPS Air Resources Division to evaluate long-range transport of airborne contaminants should also be supported, as necessary.

- *Climate Change and Influence on Water Resources* - One of the most significant natural resource issues in Alaska is climate change. Conducting investigations of climate and glacier interactions by establishing a network of study glaciers and remote weather stations has been recommended. Ground truthing information near glacier equilibrium lines in support of current research in remote sensing is needed. Many small lakes and ponds in WRST no longer contain water or have reduced in size since the 1950's and need to be studied to determine why this is occurring. Sampling trees buried and preserved by tephra deposits and old growth stands has been recommended to provide important paleoclimate data for WRST.

- *Fisheries* – There are numerous and complex fishery issues and information needs in WRST that extend beyond the objectives of this report. As a result, WRST should consider development of a park-specific Fisheries Management Plan that addresses the issues and management approaches that fit into the regional context of fisheries management. Assistance with the completion of fisheries surveys and research within the Yukon/Tana watershed is needed. Continuation of existing work to understand the effect of natural fluctuations in water quality and productivity in Tanada Lake on adult sockeye salmon returns is a high priority for WRST.

- *Non-Federal Land* - With over 700,000 acres of private, state, native, and university lands, WRST has some of the most complex land status issues in the NPS. Development of management prescriptions that minimize and mitigate all-terrain vehicle (ATV) impacts to designated trails and water resources is needed. Inventory of water resources information (i.e., wetlands mapping, stream morphological data, etc.) along McCarthy and Nabesna roads is recommended. Strategies need to be developed with the Alaska Department of Transportation for mining of material for road repair. Sensitive recharge areas need to be defined for Clear Creek and alternate water supplies at McCarthy, establishing wellhead protection areas, as appropriate. WRST needs to continue assistance with private landowners, as needed, monitoring permitted activities that influence local water resources (i.e., realignment of roadbed along Jack Creek, stream bank stabilization along Chathenda Creek at Chisana, stream diversion at Inlet Creek, erosion and flooding problems at McCarthy).

- *Navigable Waters* - The greatest hurdle to overcome in identifying and managing navigable waters in Alaska has been the differences of opinion between the state and federal government regarding the criteria of determining title navigability. Final court decisions in Alaska are still needed to provide legal guidance for accurate navigability determination. WRST staff should work with the NPS Regional Office to identify and manage navigable waters in the park and preserve.

- *Hydrologic Hazards* - Hazards associated with hydrological processes are scattered throughout WRST. Outburst floods (jökulhlaup), landslides, snow avalanches, and advancing glacial systems are hazards in the park and preserve that threaten property, transportation links, and human life. The NPS objective is to develop a better understanding of these natural processes in order to protect life and property. Where park infrastructure is present or planned or an NPS-supported action occurs, floodplain delineations may be necessary in the future to ensure compliance with the floodplain Executive Order and Directors Order. WRST should resurvey the 1995 cross-sections of the two branches of the Kennicott River at McCarthy on a scheduled frequency to calculate changes in channel/floodplain parameters and evaluate the resulting change in flood hazard for the area. Monitoring of lake stage at Hidden Creek Lake is also needed to aid in predicting timing and relative magnitude of future outburst floods. The NPS should continue participation with the interagency team's ongoing monitoring of the advancing Hubbard Glacier and associated flooding impacts to Russell Fjord. Building from the assessments conducted around McCarthy by Jones and Glass (1993) is important toward identifying areas in WRST susceptible to landslides and debris-flow hazards. Sharing the latest knowledge with staff and visitors on potential hazards associated with seasonal flooding, lake outbursts, landslides and snow avalanches is very important.

- *Coastal Management* - The harsh marine conditions along 125 miles of WRST coast increase the possibility of boating accidents that can impact coastal resources (i.e., fuel spills). An increase in cruise ship activity in Icy Bay and Yakutat Bay, elevates environmental concerns such as water discharged from cruise ships along WRST's coast that can influence nutrient concentrations in the immediate area. Inventory and monitoring of coastal resources is critical toward evaluating the efficiency and effectiveness of any spill abatement efforts.

- *Mining* - There are more than 400 abandoned mine sites in WRST. Physical impacts to the landscape from mining activities have influenced streams and associated riparian areas, changing stream morphology and increasing sedimentation. Some mining areas pose serious pollution threats to park water resources. Elevated metal concentrations and low pH have been recorded in streams at several of these sites. NPS staff needs to continue monitoring approved mining operations in WRST and the local influences on water resources. It is important to build from the 1994-1997 Geochemical Study (Eppinger et al., 2000) to further characterize metal contents in waters, soils, sediments, and vegetation surrounding the mined mineral deposits and mineral deposits that have not been extracted. Sampling of waters during high-runoff events is encouraged. Remediation of physical mining impacts (i.e., dams) to streams and associated riparian areas is needed to re-establish natural equilibrium of stream morphology and improve water quality. The NPS should be proactive in educating staff and visitors on the potential hazards associated with contaminants from areas that have been mined or undisturbed areas where a high concentration of mineral deposits naturally occur.

- *Recreation Management* - Several water-related issues that center around recreational management exist at WRST. There are approximately 600 miles of all-terrain vehicle (ATV) trails in WRST, impacting wetlands, permafrost soils, and steep slopes. WRST is encouraged to build for the 1995-1997 ATV Trail Impact Assessment and Mitigation Project, developing best management practices for ATV use and trail construction. Current ATV trails need to be evaluated through the NEPA process to determine solutions toward mitigating use on each trail. Copper, Ptarmigan and Tanada lakes have high recreational use because of their ATV and floatplane accessibility and presence of commercial lodges or spike camps. Fuel storage and waste management issues may threaten water resources in these heavy use areas. At Kennecott, National Creek is impacting historic buildings, where visitor use is seasonally high, due to an aggrading system of channel instability. WRST as requested technical assistance on this issue from the NPS Water Resources Division.

- *Wetlands Management* - Wetlands are extensive below 5000 ft. msl in WRST and have been mapped for 30 of the 117 quads in the park and preserve. It is important for WRST to establish baseline wetland information for the remaining quads to assist with separating anthropogenic impacts (i.e., ATV trail damage) from natural processes and impacts of climate change in fragile wetland environments. WRST should continue to work with the U.S. Fish & Wildlife Service (50:50 cost share Interagency Agreement) to map wetlands for 46 quadrangles in WRST. WRST is encouraged to collect wetland data to evaluate impacts to wetlands (i.e., ATV impacts) and to use the Alaska Department of Environmental Conservation's Hydrogeomorphic Approach Methodology (HGM) to assist with alternatives involving wetlands.

- *Spill Contingency Planning* - There are many potential sources for fuel spills that could impact WRST water resources (storage tanks at remote landing strips, Trans-Alaska oil pipeline, offshore oil and gas leasing, tanker accidents in the Gulf of Alaska). The NPS is severely limited in qualified personnel, spill response equipment, and baseline natural resource information to effectively respond to and evaluate impacts from fuel spills in WRST. WRST should continue to work with the interagency team on spills and emergency response procedures following the *Alaska Unified Plan* and the *Prince William Subarea Plan, Southeast Alaska Subarea Plan, and the Interior Alaska Subarea Plan.* WRST is encouraged to develop a park-specific Spill Prevention Control and Countermeasure Plan (SPCC Plan), which is required to address specific WRST facilities and hazardous waste management (i.e., fuel tank compliance, hazardous material storage and disposal compliance, etc.).

- *Water Rights* - The current data for quantifying water rights at WRST is insufficient. WRST should inventory the current water rights in the park and preserve. Along with data needed to quantify instream flow requirements, State law requires biological, recreational, or water quality data to justify the need for the requested water rights. WRST needs to develop a strategy for addressing water rights/instream flow data needs. The Tennant method (Tennant 1972, 1976) has been selected by the State as the primary method for quantifying instream flow requirements. WRST should quantitatively describe the portion of the water supply that is needed for park purposes in the Kennecott area. The park is also encouraged to work with the NPS Water Resources Division (Water Rights Branch) to determine and assert WRST's federal reserved water right in the Kennecott area.

- *Coordination* - Multi-agency coordination is essential in all Alaska park units to effectively monitor and manage the vast resources. WRST has developed several partnerships over the years to expand the effectiveness in natural resource management at the park and preserve (U.S. Geological Survey, University of Alaska-Fairbanks, Alaska Department of Fish and Game, Bureau of Land Management, U.S. Forest Service, Alaska Department of Natural Resources, Alaska Department of Transportation and Public Facilities). WRST should continue these important cooperative efforts, developing new partnerships as warranted.

Each of these issues has aspects that affect WRST's water resources, though some are not under NPS control; therefore, it is important to recognize that multi-agency communication and coordination are essential to successfully manage WRST's vast watersheds. Based on the assessment of these issues, a recommendation and justification to produce a complementary report that expands on the water-related issues and presents proposals that address the high-priority issues is presented. This Phase II process encourages other stakeholders to participate with the NPS during and after development of the second report. Phase II is designed to build from the WRSR, beginning with a Scoping Workshop where appropriate NPS staff and regional watershed stakeholders are invited to participate. The workshop objectives include identification of current information related to WRST's water resources, expanding on the issues captured in this report, and allowing workshop participants to prioritize the issues. The final product is a second report, complementary to this WRSR, which together provide a comprehensive assessment of the park's water resources and issues, including a set of recommended actions that have regional endorsement and potential partnerships. In 2004, Katmai National Park and Preserve will be the first Alaska NPS unit to complete this process.

INTRODUCTION

At 13.2 million acres, Wrangell-St. Elias National Park and Preserve (WRST) is unmatched by any other unit in the national park system. This is our largest national park, where the landscape is dominated by the eastern Alaska, Wrangell, St. Elias, and Chugach mountain ranges. WRST is one of four contiguous conservation units spanning some 24 million acres that have been recognized by the United Nations as an International World Heritage Site. The original 1978 designation included WRST and Kluane National Park Reserve in the Yukon Territory of Canada. These two areas were specifically noted for their importance in representing "incredible geological processes" namely glacier dynamics, and "premier wilderness". In 1993, both Glacier Bay National Park and Preserve and a new park, the Alsek-Tatshenshini Provincial Park in British Columbia were added to that designation. Altogether, this is the largest internationally protected area in the world.

Ernest Gruening, Director of U.S. Territories and later Alaska's governor and U.S. Senator, was the first to recommend the area as a national park or monument. After a flight over the area in 1938, he wrote a memorandum to the Secretary of the Interior:

"the region is superlative in its scenic beauty and measures up fully and beyond the requirements for its establishment as a National Monument and later as a National Park. It is my personal view that from the standpoint of scenic beauty, it is the finest region in Alaska. I have traveled through Switzerland extensively, have flown over the Andes, and am familiar with the Valley of Mexico and with other parts of Alaska. It is my unqualified view that this is the finest scenery that I have ever been privileged to see."

Several of North America's highest peaks are within the park and preserve, including Mt. St. Elias (18,008 ft. above mean sea level (msl)) and Wrangell Mountain (14,005 ft. msl), an active volcano. From these mountains flow hundreds of glaciers of varying size. The Malaspina is the largest piedmont lobe glacier (larger than the state of Rhode Island) and the Nabesna Glacier is one of the longest valley glaciers in North America (National Park Service, 1998a). Along WRST's coast, the Hubbard and Yahtse glaciers are the most active in the world (National Park Service, 1983). Glaciers spawn the numerous fluvial systems scattered throughout the park and preserve at lower elevations.

It is important for the National Park Service (NPS) to differentiate between natural versus anthropogenic-impacted environments so that mandated management is appropriately implemented for WRST's water resources. Information that is gathered through inventory and monitoring of water resources in the park and preserve can be used to determine how the water resources influence the ecosystem and are affected by changes (anthropogenic, climatic and natural) (National Park Service, 1998a). For example, a stream void of biological diversity may be the result of natural volcanic influences and not a human-induced impact; thus, the NPS would seek to maintain this natural condition.

Water Resources Scoping Report Objectives and Structure

The objectives of this Water Resources Scoping Report (WRSR) include identifying major water resources-related issues and presentation of relevant information and management considerations to better assist NPS managers with meeting their management objectives at WRST.

The report is divided into four major parts. The first part includes a description of the applicable State and Federal legislation that provides the mandates and foundation for management decisions related to water resources.

The second part contains a description of the park and preserve's natural resources, with emphasis on water resources. This section provides the reader with an overview of WRST's diverse environments, including some of the existing water-related information.

The third part is the identification of significant water-related issues pertaining to WRST management and begins to identify some of the "information needs" that will better assist NPS management in providing a greater level of water resource protection. The initial outline for water-related issues was prepared by Danny Rosenkrans (WRST).

The fourth part is the "Considerations for Future Actions". This section summarizes recommendations presented in the "Water Resources Issues" section, providing NPS management considerations for further addressing the identified issues, based on the information made available to the author. Issue-specific recommendation(s) previously proposed by NPS management via WRST planning documents (i.e., General Management Plan, Resource Management Plan) are included.

The initial information-gathering effort for this report included a 10-day visit by the author to Anchorage and WRST in 2002. During this time, the author visited several areas in WRST with park staff (i.e., Nabesna Road, Cabin Creek, Kennecott, McCarthy, Chitina River, Tana River, Iceburg Lake), which provided a better understanding of the diverse water resources and associated issues. Information was derived from many sources, including interviews with WRST and NPS-Alaska System Support Office staff, along with other Federal and State agencies (i.e., U.S. Geological Survey, Alaska Department of Environmental Conservation, etc.), and reviews of existing natural resources information with emphasis on water resources.

Location, Demography, Legislation, and Management

WRST is located approximately 200 miles east of Anchorage and 120 miles northeast of Valdez (Figure 1). The park/preserve is bounded by the Gulf of Alaska on the south, Mentasta Mountains and the Tetlin National Wildlife Refuge on the North, the Canadian border on the east, and the Copper River on the west (Figure 2) (National Park Service, 1983).

Figure 1. Regional Map, Wrangell – St. Elias National Park and Preserve

Population in the region, including the coastal communities of Valdez, Cordova, and Yakutat, and communities near the interior transportation corridors, was approximately 8600 in 1980, a 70 percent increase over 1970. This increase was generally associated with the trans-Alaska pipeline. The population has slowly grown to over 10,000 as of 2001 (Alaska Department of Labor and Workforce Development, 2003). Cordova and Yakutat are primarily fishing communities. Valdez is the terminus of the trans-Alaska oil pipeline and the site of major maintenance and loading operations. Tok is characterized by support facilities for the Alaska highway. Glennallen is the primary service center for the interior near WRST. Copper Center is the focal point of native regional activities. Numerous small communities exist throughout the region, characterized by agriculture, homesteading, mining, and a few small businesses (National Park Service, 1986).

Passage of the Alaska Native Claims Settlement Act in 1971 authorized the Federal government to withdraw and study Federal lands in Alaska for future uses. In 1978, President Jimmy Carter declared the area a National Monument because of its scientific and cultural significance. When Congress passed the Alaska National Interest Lands Conservation Act (ANILCA) in 1980, the Wrangell Mountains became part of the 13.2 million acre WRST. The importance of ANILCA to the management of WRST cannot be overstated. Not only did this legislation establish WRST, it also set into law the allowance of many activities that are not permitted in "traditional" park units located in the lower-48. Consumptive uses of natural resources such as subsistence use of fish, wildlife, and firewood in the national park and the allowance for subsistence and sport hunting in the preserve, offer a layer of complexity unique to Alaska parks.

Section 201(a) of ANILCA states that the park/preserve will be managed for the following purposes, among others:

> To maintain unimpaired the scenic beauty and quality of high mountain peaks, foothills, glacial systems, lakes and streams, valleys, and coastal landscapes in their natural state; to protect habitat for, and populations of, fish and wildlife including but not limited to caribou, brown/grizzly bears, Dall sheep, moose, wolves, trumpeter swans and other waterfowl, and marine mammals; and to provide continued opportunities, including reasonable access for mountain climbing, mountaineering, and other wilderness recreational activities. Subsistence uses by local residents shall be permitted in the park, where such uses are traditional in accordance with the provisions of title VIII.

The general purposes of the conservation system units established under ANILCA, including WRST, defined in sections 101 (a), (b), and (c), are as follows:

> To preserve for the benefit, use, education, and inspiration of present and future generations, certain lands and waters in the state of Alaska that contain nationally significant natural, scenic, historic, archeological, geological, scientific, wilderness, cultural, recreational, and wildlife values.

> To preserve in their natural state extensive unaltered arctic tundra, boreal forest, and coastal rainforest ecosystems; to protect the resources related to subsistence needs; to protect and preserve historic and archeological sites, rivers, and lands, and to preserve wilderness resource values and related recreational opportunities including but not limited to hiking, canoeing, fishing, and sport hunting, within large arctic and subarctic wildlands and on free-flowing rivers; and to maintain opportunities for scientific research and undisturbed ecosystems.

A significant percentage of lands within WRST's boundary are privately owned or selected for private ownership. While NPS regulations stemming from ANILCA and other authorities do not generally apply to private land in the park and preserve, there are numerous other federal, state and local laws that do apply. These include but are not

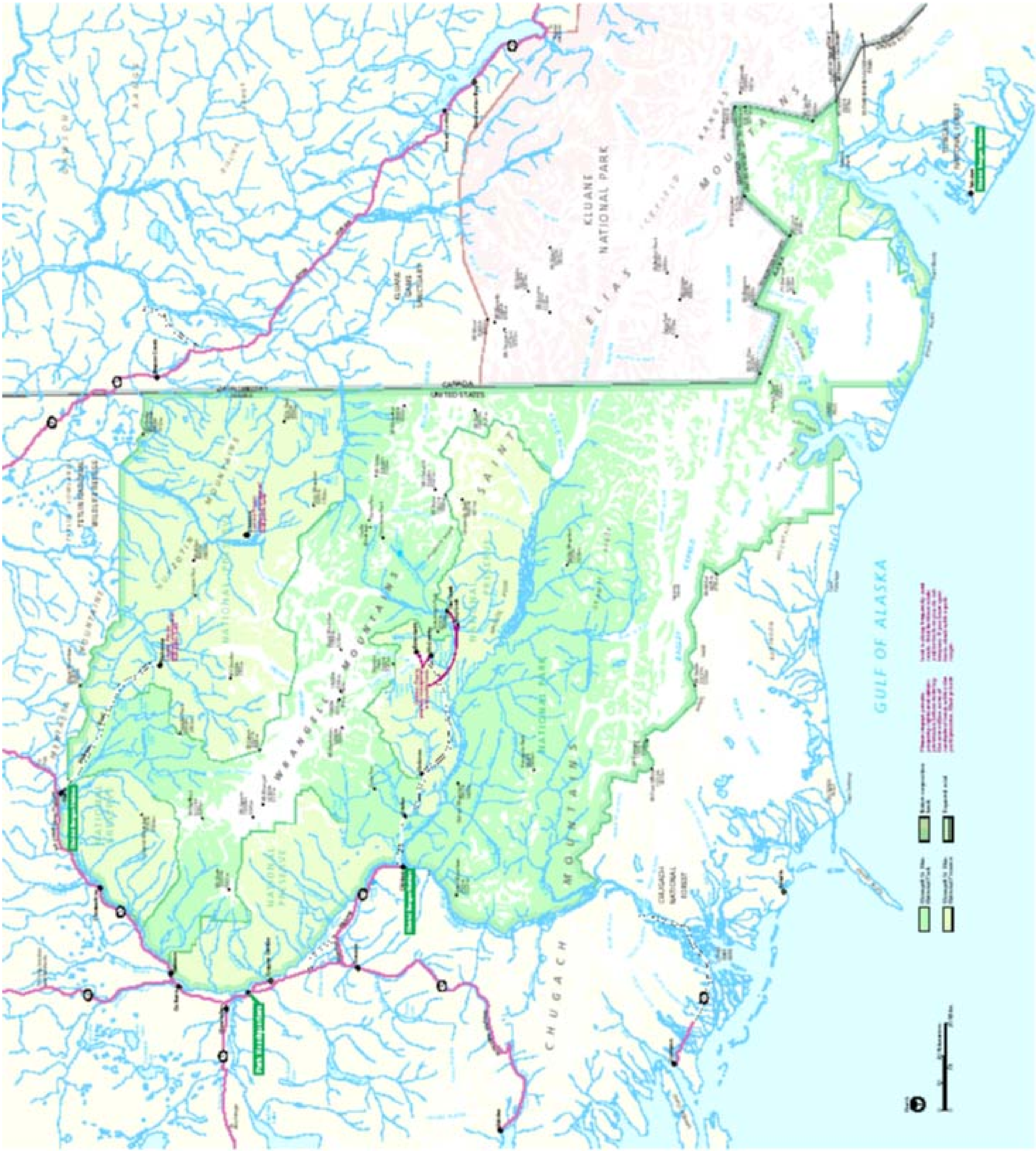

Figure 2. Wrangell – St. Elias National Park and Preserve.

limited to the Alaska Coastal Management Program, Alaska Anadromous Fish Act, Clean Water Act and Clean Air Act.

State of Alaska

State water quality laws and regulations can be found at (www.state.ak.akpages/ENV.CONSERV/). Many federal, state and local agencies have an interest, mandated or otherwise, in the water resources at WRST. Protection of water resources requires an understanding of the various policy, regulatory and management designations in order to facilitate coordination and cooperation among agencies and private landowners at WRST.

All federal lands and waters within the park and preserve boundary are under proprietary jurisdiction of the National Park Service. Both federal and state agencies have authority for the enforcement of appropriate regulations. Water laws and regulations at the state and local level are often patterned after federal laws, or serve in response to federal directives.

Federal

Some additional legislation and executive orders that help guide management of WRST's aquatic resources are presented in this section. For further information access the web pages for the U.S. Environmental Protection Agency (www.epa.gov) and the U.S. Fish and Wildlife Service (www.fws.gov).

> Section 203 of ANILCA directs WRST to be administered pursuant to the NPS Organic Act. The *National Park Service Organic Act* of 1916 established the NPS and mandated that it "shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of future generations."
>
> The *General Authorities Act* of 1970 reinforced the 1916 *Organic Act* – all park lands are united by a common preservation purpose, regardless of title or designation. Hence, federal law protects all water resources in the national park system equally, and it is the fundamental duty of the NPS to protect those resources unless otherwise indicated by Congress.
>
> The *Redwood National Park Act* (1978) amended the *General Authorities Act* of 1970 to mandate that all park system units be managed and protected "in light of the high public value and integrity of the national park system." Furthermore, no activities should be undertaken "in derogation of the values and purposes for which these various areas have been established", except where specifically

authorized by law or as may have been or shall be directly and specifically provided for by Congress.

The *National Parks Omnibus Management Act* of 1998 attempts to improve the ability of the NPS to provide state-of-the-art management, protection, and interpretation of and research on the resources of the national park system by:

- Assuring that management of units of the national park system is enhanced by the availability and utilization of a broad program of the highest quality science and information;
- Authorizing the establishment of cooperative agreements with colleges and universities, including but not limited to land grant schools, in partnership with other Federal and State agencies, to establish cooperative study units to conduct multi-disciplinary research and develop integrated information products on the resources of the national park system, or of the larger region of which parks are a part;
- Undertaking a program of inventory and monitoring of national park system resources to establish baseline information and to provide information on the long-term trends in the condition of national park system resources, and;
- Taking such measures as are necessary to assure the full and proper utilization of the results of scientific study for park management decisions. In each case in which an action undertaken by the NPS may cause a significant adverse effect on a park resource, the administrative record shall reflect the manner in which unit resource studies have been considered. The trend in the condition of resources of the national park system shall be a significant factor in the annual performance.

Congress passed the *National Environmental Policy Act* (NEPA) in 1969, which requires that federal actions which may have significant environmental impacts shall: "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment."

The *Clean Air Act* of 1970 (as amended) regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The 1990 amendments to this act were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground level ozone, stratospheric ozone depletion and air toxics. The amendments identify a list of 189 hazardous air pollutants. The U.S. Environmental Protection Agency must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations.

The 1972 *Federal Water Pollution Control Act*, more commonly known as the *Clean Water Act*, was designed to restore and maintain the integrity of the nation’s waters. States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water quality standards. Section 404 of the act requires that a permit be issued for discharge of dredged or fill materials in waters of the United States, including wetlands. The U.S. Army Corps of Engineers administers the Section 404 permit program. Section 402 of the act requires that a National Pollutant Discharge Elimination System (NPDES) permit be obtained for the discharge of pollutants from any point source into the waters of the United States. In general, all discharges and storm water runoff from major industrial and transportation activities, municipalities, and certain construction activities must be permitted by the NPDES program. The U.S. Environmental Protection Agency usually delegates NPDES permitting authority to the state.

The *Endangered Species Act* of 1973 requires the NPS to identify and promote the conservation of all federally listed endangered, threatened, or candidate species within any park unit boundary. This act requires all entities using federal funding to consult with the Secretary of Interior on activities that potentially impact endangered flora and fauna. It requires agencies to protect endangered and threatened species as well as designated critical habitats. While not required by legislation, it is NPS policy to also identify state and locally listed species of concern and support the preservation and restoration of those species and their habitats.

Executive Order 13112: *Invasive Species* complements and builds upon existing federal authority to aid in the prevention and control of invasive species.

Executive Order 11990: *Wetlands Protection* directs the NPS to 1) provide leadership and to take action to minimize the destruction, loss, or degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) to avoid direct or indirect support of new construction in wetlands unless there are no practicable alternative to such construction and the proposed action includes all practicable measures to minimize harm to wetlands.

Executive Order 11988: *Floodplain Management.* The objective of the E.O. is, “…to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is an practicable alternative.” For non-repetitive actions, the E.O. states that all proposed facilities must be located outside the limits of the 100-year floodplain. If there were no practicable alternative to construction within the floodplain, adverse impacts would be minimized during the design of the project.

Executive Orders 11644 and 11989: *Off-Road Vehicle Use*. These executive orders require Federal land managers to control off-road vehicle (ORV) use on public lands. Executive Order 1164 requires the designation of trails and areas, which are based on the protection of the resources of lands. Executive Order

11989 requires Federal agencies to close areas of ORV use if it is causing or will cause adverse affects on soil, vegetation, wildlife, habitat, cultural or historic resources.

Director's Order #2: Park Planning provides the policies and guidance related to park planning. The Park Service has a mandate in its Organic Act and other legislation to preserve resources unimpaired for the enjoyment of future generations. NPS park planning will help define what types of resource conditions, visitor uses, and management actions will best achieve that mandate. The NPS is to maintain an up-to-date General Management Plan (GMP) for each unit of the national park system. The purpose of the plan is to ensure that each park has a clearly defined direction for natural and cultural resource preservation and visitor use. WRST completed a GMP in 1986. A park's Resources Management Plan (RMP) describes the specific management actions needed to protect and manage the park's natural and cultural resources. WRST's RMP (1998) identifies existing resources and conditions, present actions, and identifies future needs consistent with legislative and administrative guidance, resource significance, and other park planning documents. Discipline-specific planning documents that complement the RMP (e.g., Fire Management Plan, Water Resources Scoping Report, etc.) are prepared for NPS units when warranted.

Based on these legislative mandates and NPS policies the objectives for WRST's natural resources management are (National Park Service, 1998a):

- To manage natural resources for the purpose of perpetuating ecological systems and for the education and enjoyment of this and future generations.
- To consider humans an integral part of the ecosystem, and to encourage traditional users of the park and preserve's natural resources to understand and respect ecosystems and to maintain the natural balance.
- To assure the preservation of wilderness resource values and related wilderness recreational opportunities.
- To elicit the cooperation of knowledgeable individuals, groups, institutions, and agencies in collecting current and complete information and data about the natural resources.
- To the fullest extent possible, allow natural processes to determine the shapes and substances of the environment.
- To work cooperatively and inter-dependently with the Alaska Department of Fish and Game, the Alaska Boards of Game and Fisheries and the Federal Subsistence Board in regulating consumptive uses of fish and wildlife resources.
- To the greatest extent possible, maintain rivers in their free flowing state and conduct river studies and prepare river management plans.
- To elicit the cooperation of mining interests to maintain high environmental standards for the protection and preservation of natural resources.
- To devise the best possible means of management and operations to protect critical wildlife and their habitats.

- To maintain opportunities for scientific research in undisturbed ecosystems.
- To work cooperatively and inter-dependently with Parks Canada in areas of mutual concerns about natural resources.

DESCRIPTION OF NATURAL RESOURCES

Climate

WRST spans three of the state's four climatic zones recognized by the National Weather Service: *maritime, transitional*, and *continental*. The *arctic* is the only zone not represented (National Park Service, 1986). Storm centers, which originate in the "Aleutian Low", track northeastward into the coastal mountains of Alaska. Interaction between these storm centers, polar highs and extreme relief of the St. Elias region produce some of the northern hemispheres highest precipitation and temperature gradients (National Park Service, 1998a). As a result, precipitation and air temperature vary in WRST depending on the geographic location. The climate is typically warmer and wetter along WRST's coast, where the relative thermal homogeneity in the Gulf of Alaska surface waters is translated into a moderate and uniform maritime climate (Uda, 1963). At Glennallen, which is representative of WRST's inland "continental" climate conditions, the mean air temperature ranges from –6.4º F in January to 56.5º F in July (Figure 3). At Yakutat, which represents coastal climate conditions along the Gulf of Alaska, the mean air temperature ranges from 25.2º F in January to 53.6º F in July. The park's higher elevations experience much lower temperatures, depending on altitude. The mean annual precipitation for Glennallen is 10.4 inches, increasing to 151.2 inches along the coast at Yakutat (Figure 3) (National Climate and Data Center, 2002). WRST's mountains serve as a barrier between the moist maritime air from the Gulf of Alaska and dry continental air from the interior (National Park Service, 1986).

Physiography

The mountains in WRST are part of the Pacific Mountain System, a belt of parallel mountain ranges separated by intervening lowlands bordering the Pacific Ocean. Lowlands are extensive only in the region's center and along its western and northwestern fringes. Elsewhere, the lowlands are sandwiched between mountains and sea, or occur as narrow valleys and plateaus grading into uplands and serrated peaks (U.S. Department of the Interior, 1974). The coast of WRST borders the Chugach and St. Elias mountains. Terrain is varied, with beach and dune ridges running parallel to the coast and glacial moraines and outwash plains widespread. Elevated marine terraces as high as 800 feet above sea level are present inland. A couple of large fjords, Icy Bay and Disenchantment Bay, indent the otherwise straight coastline. The region can be divided into four physiographic provinces, see Table 1 (Warhaftig, 1965).

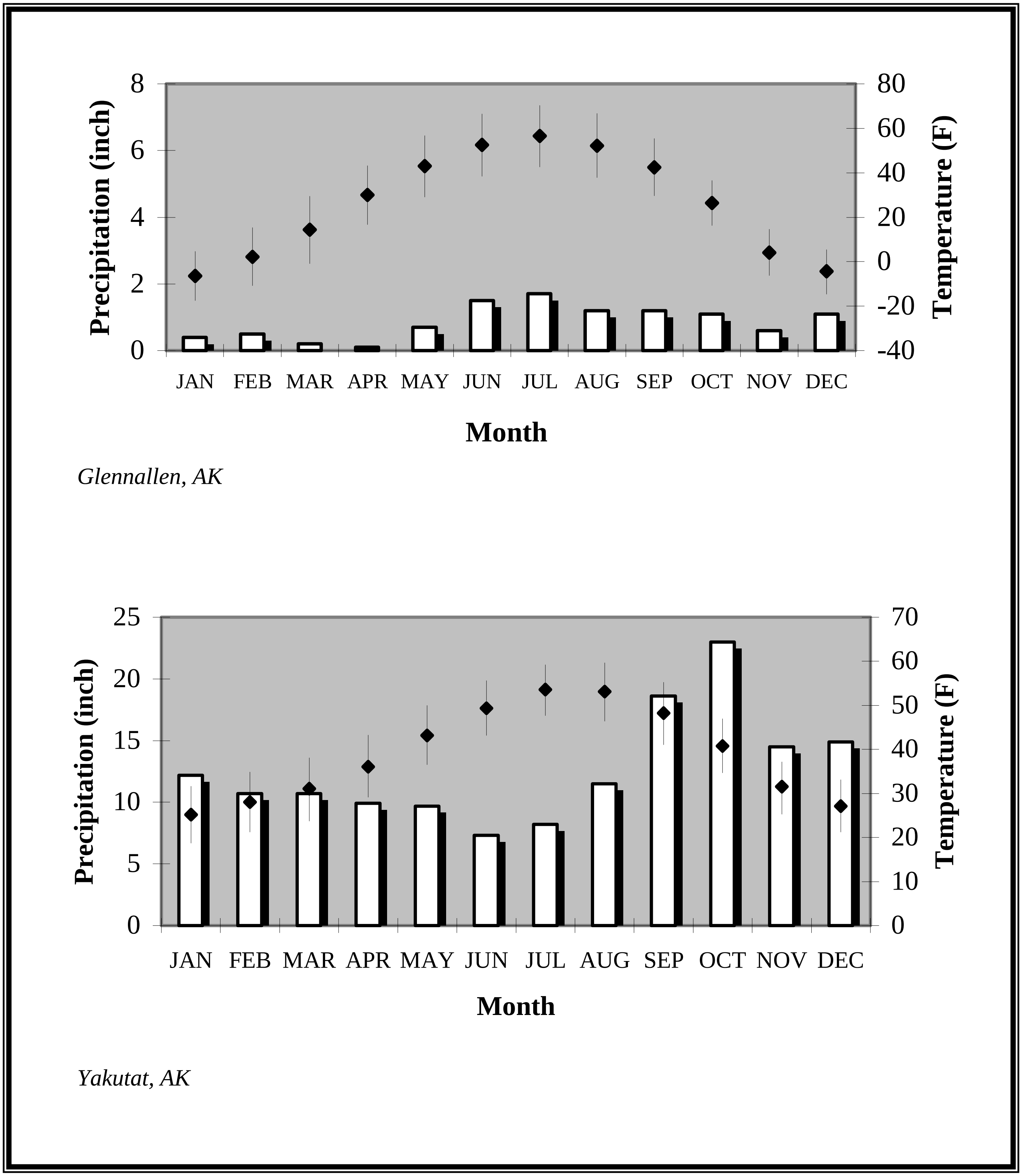

Figure 3. Monthly mean precipitation (bars) and air temperature range (diamond-whiskers) (1961-1990), Glennallen and Yakutat, Alaska (National Climate and Data Center, 2002).

Table 1. Physiographic units in Wrangell-St. Elias National Park and Preserve (north to south) (U.S. Department of the Interior, 1974).

Provinces	**Sections**
Northern Plateaus	Northway-Tanacrass Lowland
Alaskan-Aleutian	Central and Eastern Part (Mentasta-Nutziotin Mtn segment)
Coastal Trough	Copper River Lowland
Coastal Trough	Duke Depression
Coastal Trough	Wrangell Mountains
Pacific Border Ranges	Kenai-Chugach Mountains
Pacific Border Ranges	St. Elias Mountains
Pacific Border Ranges	Gulf of Alaska Coast

The NPS Alaska Regional Office has recently delineated *Ecosystem Regions* for all Alaska national park units, including WRST (National Park Service, 2001a). The ecological boundaries for WRST were delineated by synthesizing data from the following references:

- High-altitude color IR aerial photographs (1:60,000, 1978-86).
- Geologic maps for major bedrock and surficial geologic features.
- Soil maps for part of the Copper River Basin; and
- Land cover maps from Thematic Mapper satellite imagery classified into twenty vegetation and other land cover classes.

Because the map and write-ups in the National Park Service (2001a) report are based almost entirely from remotely-sensed data interpretation during the spring and summer of 2001, they should be considered preliminary. The level of detail for the eight *Ecosystem Regions* and 64 *Ecological Subsections* (a more detail delineation of WRST's *Ecosystem Regions*) in WRST extends beyond the scope of this report (see Appendix A), but is an important information source for NPS staff and others to reference, as needed.

Geology

The Wrangell Mountains, which form much of WRST, are made up largely of numerous lava flows that have been erupted mostly from large broad volcanoes during the past 26 million years. This extensive volcanic terrain, which is called the Wrangell volcanic field, covers about 4,000 mile square (10,400 km^2) and extends eastward from the Copper River Basin through the Wrangell Mountains, into the St. Elias Mountains of Alaska and the Yukon Territory of Canada.

The principal basement rocks on which the Wrangell volcanoes erupted are much older rocks and have had a complex geologic history. These rocks belong to what is referred to in the geologic literature as the Wrangellia terrane, which is part of an even larger group of exotic terranes - the Wrangellia composite terrane - that has been accreted to Alaska and the North American Continent during the past few hundred million years. On the basis of geophysical and fossil evidence, rocks of the Wrangellia terrane were formed in a tropical environment thousands of miles south of its present position. The Wrangellia terrane began as a volcanic arc about 300 million years ago, probably along the margin of an ancient North American continent. As arc-related volcanic activity waned, a rift developed between the arc and continent, allowing the eruption of thousands of cubic miles of basalt lava flows that flooded and filled the rift-formed basin. Subsequently, shallow warm seas inundated the land, depositing layers of marine limestone and other sediment on the volcanic rocks.

During the next 200 million years, the Wrangellia terrane was gradually transported northward, where it was welded to other terranes and eventually docked against western North America about 100 million years ago. It now forms a belt extending from southern Alaska to southern British Columbia. Subsequently, other terranes, such as those composing the Southern Margin composite terrane, have been carried northward and accreted to continental Alaska. The last terrane to arrive, the Yakutat terrane, docked about 26 million years ago, concurrent with and partly responsible for the development of the Wrangell volcanic field.

The Wrangells include exposed deformational structures that reflect at least three major episodes of mountain building. Over the entire area, rock units are folded, faulted, twisted and stretched, often in a spectacular manner (Shaine et al., 1973). Deformation occurs at all scales, recording the dynamic history of this landscape.

Mining

The complex geology of WRST has produced a variety of important mineral deposits. The first gold discovery in the northern Wrangell Mountains was on Jacksina Creek near the headwaters of the Nabesna River in 1899. In that same year, Oscar Rohn, on his exploration of the upper Chitina Valley, found rich pieces of chalcocite ore in the glacial moraine of Kennicott Glacier and pointed out similarities to the rich copper deposits of Michigan's Lake Superior District. A year later, prospectors traced the chalcocite to deposits on Bonanza Ridge, which eventually became the incredibly rich Bonanza Mine, one of five mines that supplied copper and silver ore to the now-historic Kennecott Mill.

The Kennecott mines did not go into full production until 1911, when the completion of a 196-mile-long railroad from Cordova, near the mouth of the Copper River, to the Kennecott mining town allowed transport of the rich copper concentrate. In 27 years of operation, over a billion pounds of ore valued at $100 to $300 million were hauled on the railroad.

The mine and the railroad were abandoned in 1938, when the rich ore was exhausted. The railroad bed now provides the base for most of the Chitina-McCarthy Road along the south flank of the Wrangell Mountains in the heart of Wrangell-St. Elias National Park and Preserve.

Gold discoveries in the Nabesna area led to construction of the Nabesna Road, which was built in the early 1930's and used to haul gold ore from the now-closed Nabesna Mine. Today, the Nabesna Road provides vehicle access along the north side of the Wrangell Mountains into WRST.

Soils

Currently, there has been no comprehensive soil surveys conducted in WRST (Natural Resources Conservation Service, 2002). According to the U.S. Department of the Interior (1974), there are two main soils on the upper and middle slopes. One group is dominantly loamy, poorly drained, and underlain with permafrost (*Histic Pergelic Cryaquepts*). The other contains well-drained; very gravelly, loamy textured; moderately-deep to deep soils over bedrock (*Typic Chryochrepts*). The southern portion of the unit, the Copper River-Chugach, also has areas of well-drained, very shallow drift or colluvium over rock (*Pergelic Lithic Cryumbrepts*). On the lower slopes, the soils are also dominantly loamy. They may be poorly drained with permafrost or deep, well-drained gravelly material over bedrock. Permafrost is extensive in the region, except along the coast. It is most prevalent and deep in shaded, moist, fine-soiled, moss-insulated areas. Coarse-grained soils along watercourses and on south facing slopes are most likely to be free of this frozen condition. Permafrost in soils can influence subsurface drainage. Permafrost can also cause unstable soil conditions on sloping ground, and melts readily when disturbed, causing irregular subsidence (National Park Service, 1986).

National Park Service (2001a) provides a description of soils for each of the Ecological Subsections delineated in WRST. The information is based on aerial photograph interpretation of vegetation and landforms and is somewhat speculative (outside the area covered by Clark and Kautz, 1990).

Hydrology

<u>Watersheds</u>

Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6 digit accounting units and the 8 digit cataloguing units are generally referred to as basin and sub-basin. It is defined as the Federal Information Processing Standard (FIPS) and generally serves as the backbone for the country's hydrologic delineation. The 8 digit cataloguing units that include WRST are Yakutat Bay (19010401), Bering Glacier (19010402), Lower Copper River (19020104), 19020103 (Chitina River), Middle Copper (19020102), Nabesna-Chisana Rivers (19040501), and Upper Copper River (19020101).

Surface Water

The streamflow pattern in the Wrangell's region is dominated by three major mountain features, the Wrangell-St. Elias, the Chugach and the Nutzotin mountains. The headwaters, which include glaciers and large icefields, dominate the annual runoff pattern, delaying large river flows until the late summer when glacial-melt waters are at a maximum (U.S. Department of the Interior, 1974).

Freshwater Environments

Freshwater is a critical component among many of the ecosystems within WRST. It is a major mechanism for distributing sediment, organic matter, and nutrients, which determine levels of biotic processes in lakes, rivers, and marine environments. With over 25% of the landmass in WRST covered by glacier or permanent snowfield, it contains one of the largest freshwater reserves in the northern hemisphere.

Lakes and Ponds

Within the lower elevations of WRST, numerous small ponds and lakes exist. Most of the lakes were formed by past glacial gouging. Lakes that are fed by glacial meltwater have turbid waters. Biological productivity and the presence of fish varies among these glacial fed lakes dependent upon the contribution of glacial meltwater and the associated light transmission (National Park Service, 1990a).

Shallow closed-basin tundra ponds feed the headwaters of several of the streams in the park and preserve. Water in these systems is usually clear and slow moving, and vegetation in the ponds is abundant. Many of the tundra ponds support aquatic invertebrates and waterfowl, and several support fish populations (National Park Service, 1990a).

The physical, chemical and biological characteristics of three lakes in WRST (Copper, Ptarmigan and Tanada lakes) were surveyed in 1991-1992. Copper and Tanada lakes located south of Nabesna Road, drain into the Copper River basin. Ptarmigan, located on the northeastern boundary of WRST, drains into the White River basin in Canada. Bathymetric maps provided by the Alaska Department of Fish and Game show that both Copper Lake and Tanada Lake are deep, with Copper Lake having a maximum depth of 73 meters and Tanada Lake having a maximum depth of 54 meters. Ptarmigan Lake is not nearly as deep, with a maximum depth of 12 meters (National Park Service, 1994a).

The amount of surface area covered by many small lakes and ponds in WRST has reduced in size over the past 25 years. The cause is undetermined and may be the result of natural successional or climatic processes (National Park Service, 1998a).

South-central and southeastern Alaska is one of the world's major concentrations of lakes dammed by glacial ice, with over 100 in WRST (Rosenkrans, pers. comm., 2003). These lakes are distributed unevenly through the first three mountain ranges inland from the coast, typically in the lower 8.7 miles of the damming glaciers (Stone, 1963).

Rivers and Streams

There are six major river systems that originate within WRST: Copper, Chitina, White, Bremner, Nabesna, and Chisana rivers. The Copper River is the major watercourse in the region, forming the western boundary of the WRST. An estimated 38 million acre feet of water flow into the Gulf of Alaska annually from the Copper River watershed (National Park Service, 1998a). Although the annual mean discharge of the lower Copper River is 57,400 cfs, most of the flow occurs during the summer months from snowmelt, rainfall, and glacial melt (Brabets, 1997). It has been estimated that 85% of the flow occurs between May 1 and October 31 (National Park Service, 1986).

Minimal work has been conducted in WRST to measure the geomorphic parameters of the rivers and streams. Jones and Glass (1993) provided channel and flood characteristics at selected sites above Chitina in the Chitina River drainage (Table 2). Many of the fluvial systems in WRST are very dynamic due to the environmental setting (e.g., sediment loading from landslides, flooding from glacier-dammed lake outbursts, etc.) and changes in stream geometry are common.

Table 2. Bankfull channel characteristics at selected sites in Chitina River drainage (Jones and Glass, 1993).

Stream Name	Width (ft)	Depth (ft)	X-Section Area (ft^2)	Slope
Chititu Creek near May Creek	50	2.30	115	0.0067
May Creek near May Creek	16	2.00	32	0.0057
Kennicott River main channel at McCarthy	277	7.57	2,100	0.0104
Kennicott River overflow channel at McCarthy	216	9.07	1,960	0.0124
McCarthy Creek at Green Butte Mine above landslide	38	4.82	183	0.0182
McCarthy Creek above east fork McCarthy Creek	76	3.18	242	0.0127
Nikolai Creek at mouth near McCarthy	25	2.71	68	0.0728
McCarthy Creek near McCarthy	90	3.02	272	0.0158
Stelna Creek near Chitina	27	1.80	49	0.0150

All major rivers and streams in WRST drain glaciers and consequently transport large amounts of silt during the summer. Such waters seldom have substantial resident fish populations, but provide migration routes from the ocean to spawning and wintering grounds in clear water tributaries and lakes. Glacial streams, in general, have higher gradient, higher sediment load, higher turbidity, greater scouring effect, and lower biotic productivity than non-glacial streams. The flow in these glacial streams is greatest from May through September, with peak flow generally occurring in July, when the highest seasonal temperatures cause the maximum melting of glacial ice and snow (National Park Service, 1990a). The deposition of part of the sediment load causes many glacial streams to develop braided streambeds and wide channels and floodplains. The major drainages in WRST carry some of the highest suspended sediment loads measured in the state of Alaska (in excess of 2,000 mg/L at high flow) (National Park Service, 1990a).

The more productive non-glacial (clear water) streams, limited in occurrence, are of great importance for fish spawning. The major clear water streams in WRST include Tebay River, Hanagita River, Lakina River, Clear Creek, and Beaver Creek (National Park Service, 1986) (Sharp, pers. comm., 2003). These streams are located in areas fed by rain, snowmelt, and groundwater resulting in clear systems with low suspended sediment loads (< 50 mg/L), except during high flow. Flow reaches a peak in non-glacial streams in April and May. Flows typically decline in June, July, and August with the lowest stream flow from September through March. Non-glacial streams are typically not braided like the typical glacial streams, flowing in a single channel with riparian vegetation established along the channel (National Park Service, 1990a).

Rivers and streams are an important recreational resource, providing floating and sport fishing opportunities in the summer, and when frozen, providing primary transportation routes for winter access. All rivers in WRST are to be managed so that they remain in a free-flowing state, their shorelines remain primitive, and their waters remain unpolluted. The Federal Power Act does not allow the Federal Energy Regulatory Commission to license power facilities in areas within the national park system (National Park Service, 1986). Studies by the Bureau of Outdoor Recreation have concluded that the Bremner, Copper and Chitina rivers qualify as potential additions to the National Wild and Scenic Rivers system (U.S. Department of the Interior, 1974).

Wetlands

Wetlands dominate the lower elevations in WRST and include areas adjacent to streams and lakes, wet tundra, shallow tundra ponds, wet shrub scrub and forested wetlands. Many of the wetlands in the park/preserve support aquatic invertebrates, fish populations and waterfowl. The northern wood frog, the only amphibian in interior Alaska, is also found in WRST's wetland habitats (National Park Service, 1990a).

Wetlands represent transitional environments, located between uplands and deepwater areas. Flora within these wetland systems exhibit extreme spatial variability, triggered by very slight changes in elevation. Temporal variability is also great because the surface water depth is highly influenced by changes in precipitation, evaporation and/or infiltration. Cowardin *et al.* (1979) developed a wetland classification system that is now the standard in the federal government. In this system, a wetland must have one or more of the following attributes: (1) at least periodically, the land supports predominately hydrophytes; (2) the substrate is predominately undrained hydric soil; and (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year. There are four federal government agencies responsible for identifying and delineating wetlands: the U.S. Army Corps of Engineers, Environmental Protection Agency, Fish and Wildlife Service, and Soil Conservation Service.

Snow, Ice and Glaciers

Glaciers are the dominate sculptor that has produced today's landscape in WRST. Today glaciers cover approximately 20 percent of the 13 million acres within the park and preserve (National Park Service, 1998a). The coastal Chugach and St. Elias mountains are virtually inundated by icefields covering about 4 million acres of which the 80-mile-long Bagley Icefield is the longest (U.S. Department of the Interior, 1974).

Seasonal ice and snow cover affects the characteristics of aquatic ecosystems. They control the amount of light reaching the unfrozen water beneath the ice (Prowse and Stephenson, 1986). Ice can also prevent gas exchange between underlying waters and the atmosphere and may commonly lead to depletion of dissolved oxygen and the build up of reduced gasses such as CO_2, CH_4 and H_2S (Rouse et al., 1997). The processes accompanying ice formation during freeze-up and break-up have a wide range of effects on the bed, banks, and biota of lakes and rivers. These include frazil ice (aggregate of ice crystals formed in supercooled turbulent water) impact on fish and invertebrates, anchor ice growth, elevated water levels, channel blockage and increased scouring (Prowse, 1994).

Glacier ice is a metamorphic rock that consists of interlocking crystals of the mineral ice and owes its characteristics to deformation under the weight of overlying snow and ice. Snow that survives a year or more gradually increases in density until it is no longer permeable to air, at which point it becomes glacier ice. Although now a rock, such ice has a density of about 0.9 g/cm^3 and will float in water (Skinner and Porter, 1992). Glaciers generate their own stream systems, either on their surface or within and below the ice, in a similar manner to streams in limestone regions. During the peak period of melting in early summer, the stream that emerges at the terminus of a glacier is often a spectacular torrent, frequently flooding the valley floor below. Yet in winter, discharge is reduced to a mere trickle or locked solid. These extremes between summer and winter provide a fascinating range of meltwater features on and around glaciers (Hambrey and Alean, 1994).

The mass of a glacier is constantly changing as the weather varies from season to season and, on longer time scales, as local and global climate change. These ongoing environmental changes cause fluctuations in the amount of snow added to the glacier surface and in the amount of snow and ice lost by melting (Skinner and Porter, 1992).

The development of meltwater channels on the surface of a glacier depends on the rate of melting, the rate of deformation of the ice, the extent of crevasses and the pattern of other structures. Surface channel systems develop best on stagnant and on cold glaciers, but will not appear at all on those with a large number of crevasses. Not a great deal is known about the internal drainage systems of glaciers. Nevertheless, through the use of dye tracers it is possible to monitor how fast water travels through them (Hambrey and Alean, 1994).

Coastal Environments

There have been some comprehensive studies of coastal circulation in the Gulf of Alaska as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the Bureau of Land Management and the National Oceanic and Atmospheric Administration (Reed et al., 1981). This work allowed a fairly detailed specification of the coastal flow regime in the northeast Gulf of Alaska near Yakutat. Along the northwest Gulf of Alaska (Prince William Sound –Copper River area through the Shelikof Strait), a well-defined westward coastal current is present known as the Kenai Current. In the northeast Gulf of Alaska, however, the sea-level data indicate little evidence of well-developed baroclinic coastal flow (driven by pressure gradient from freshwater drainage) near Sitka and Yakutat, with maximum net flow in winter during the period of maximum winds (Reed et al., 1981).

Portions of two glacial fjords are within WRST's coastal boundary, Icy Bay and Disenchantment Bay. Within them, water exchange may be partially restricted by sills near their entrances, over which the less dense and less saline surface water flows freely outward, but inward flow of the more dense marine water may be restricted. Upward mixing of salt causes surface salinity to increase with distance from the fjord head. Vertical circulation occurs primarily in winter. Nutrients are increased, both from terrestrial runoff and from upwelling of deeper waters (U.S. Department of the Interior, 1974).

Tidewater glaciers are very active along WRST's coast. Rapid advance of the Hubbard Glacier in 2002 closed off Russell Fjord at the head of Disenchantment Bay, causing waters in the fjord to rise 61 feet behind the ice wall before it broke, releasing peak flows of 1.8 million cfs into the bay.

Volcanic Environments

Volcanic activity occurred in three separate eras – Paleozoic, Mesozoic, and Cenozoic – in the Wrangell and part of the St. Elias mountains. Major eruptions have occurred as recently as 1,500 years ago (Lerbekmo and Campbell, 1969).

Most of volcanoes of the western Wrangell mountains are unlike other volcanoes located around the Pacific rim. Rather than erupting explosive lavas forming steep-sided cones, they have been built by the accumulation of hundreds of relatively fluid lava flows to form broad mountains with gentle slopes, typical of shield volcanoes. Now only youthful Mount Wrangell still displays a shield-like form; the other, generally older volcanoes have had much of their superstructure removed by glacial and other erosional processes.

On the western flank of Mt. Drum are three large thermal springs known as mud volcanoes (Figure 4): Shrub, Upper Klawasi, and Lower Klawasi (Nichols and Yehle, 1961). These three mud volcanoes of the Klawasi group are evidence for the existence of a warm and possibly a hot water hydrothermal system in the Copper River Valley. These thermal springs are characterized by carbon dioxide gas and warm sodium bicarbonate and sodium chloride waters (Nichols and Yehle, 1961). A field visit in 1999 found the hot springs discharge to be similar, but somewhat more widespread than in the previous two years, with evidence of animal and vegetation deaths from carbon dioxide exposure in the immediate area (Sorey et al., 2000). Maximum fluid temperatures in each of the three main discharge areas, ranging from 48-54°C, were equal to or higher than those measured in the two previous years (Sorey et al., 2000). The origin of the saline water in the Copper River Basin is not known with certainty (Hawkins and Motyka, 1984). Motyka et al. (1989) believe that an igneous intrusion is releasing carbon dioxide and causing metamorphic decarbonation of limestone beds beneath the Klawasi group of mud volcanoes. The high arsenic concentrations suggest that the basal portion of the Chitiston limestone is the source of the metamorphic carbon dioxide (Motyka et al., 1989). The major growth of the Shrub and Upper Klawasi cones ceased prior to the last major glaciation, but intermittent activity has continued on a minor scale to the present. The Lower Klawasi mud volcano, one of the largest cones in the region, was formed principally in post-glacial time (Nichols and Yehle, 1960).

Figure 4. One of three mud volcanoes located in Wrangell-St. Elias National Park and Preserve.

The western Wrangells area captured the interest of the state of Alaska and U.S. Geological Survey due to the potential for geothermal energy development (National Park Service, 1986). Extreme climatic conditions in Alaska and the lack of transportation infrastructure and viable markets make geothermal energy unprofitable for extraction. The Bureau of Land Management has never issued a geothermal steam lease in Alaska and no sales are scheduled in the foreseeable future (Barr, 2001).

<u>Groundwater</u>

Groundwater in WRST is found primarily in areas of unconsolidated sand, gravel, silt, and clay. Water may flow from the aquifer into a surface water source, or the surface water may recharge the aquifer, depending on relative water levels. Groundwater is more abundant along the major streams of the basin. Wells drilled in lowland areas produce water from unfrozen floodplains and alluvium at depths generally less than 40 feet. For example, well depths in lowland areas at Slana and Glennallen are 20 feet (National Park Service, 1990a).

Some basic hydrogeologic principles can be inferred from the park's geology and geomorphic features. For example, glacial deposits can influence local groundwater flow. At McCarthy, water percolating into moraine gravels and interbedded fluvial deposits travel downwards until intercepted by the underlying basalt bedrock. The ground water then travels as sheetflow at or near the moraine and basalt interface, and along the more porous fluvial deposits (Martin, 1993)(Rosenkrans, pers. comm., 2003). Streams that issue from the edge of glaciers pick up large loads of unconsolidated sediments, dumping the coarser materials some distance downstream. These outwash gravels occur in the form of outwash fans and outwash terraces and constitute another productive aquifer system. Where moraines dam melt water, fine-grained sediments can accumulate producing aquitards or confining beds (Mandel and Shiftan, 1981).

WRST also contains coastal aquifers that are influenced by salt water, and aquifers contained in crystalline rocks (igneous units) that are influenced by faults and fractures. Based upon the variability in WRST's hydrogeologic characteristics, ground water flow, depth, quantity, and quality can differ greatly over very short distances.

Water Quality

WRST is bounded such that upper portions of virtually all watersheds are completely contained. Thus, the potential for protection of WRST's water quality is good (U.S. Department of the Interior, 1974). Water quality standards for the state of Alaska can be found on the Alaska Department of Environmental Conservation's website (http://www.state.ak.us/dec/title18/title70wqs.pdf).

Most of the glacial streams in WRST have a pH near neutral (7.0). Hardness, alkalinity, and heavy metal concentrations vary among streams due to the different geologic formations with which the water comes in contact. Most glacial streams, however, fall in the moderately hard category (75 – 150 mg/L calcium carbonate) and all stream waters show a degree of natural mineralization. High sediment loads and turbidity also characterize these glacially fed systems. Water temperatures in glacial streams remain near freezing throughout the summer due to the daily input of glacial meltwater (National Park Service, 1990a).

The majority of non-glacial streams in the park/preserve have a pH near neutral, except for a few streams, which drain iron sulfide areas and have pH values less than 6. Similar to the glacial streams, hardness concentrations vary due to varying geology with moderately hard water (75 – 150 mg/L calcium carbonate). Suspended sediment loads are typically low (< 50 mg/L) for these non-glacial systems, with low turbidity except during high flow conditions. Due to the highly mineralized geology, instream metal concentrations can be relatively high (National Park Service, 1990a).

There is little specific information available for the several rivers and streams within the park and preserve boundary. In the Final Environmental Impact Statement on cumulative impacts of mining in WRST (National Park Service, 1990a), streams located at Nabesna, Chisana, Nizina, and Kennicott were discussed with some of the specifics from that report presented below. It should be noted that the following water quality discussions are limited to data collected during "low flow" conditions, except where noted, when concentration of pollutants would likely be minimal.

<u>Nabesna (located in northcentral WRST)</u>

> *The streams of the Nabesna study area are nonglacial. Unconsolidated gravels allow for surface water and ground water exchange.*
>
> *Cabin Creek*: a small clear water stream that originates on the peaks west of the Nabesna mine and flows east to Jack Creek. For approximately one-half mile, Cabin Creek flows underground during low and moderate flow. The physical stream channel is essentially undisturbed before passing through some of the mine tailings, where the water quality is altered. In 1986, total recoverable manganese, zinc, iron, hydrogen sulfide and conductivity measurements were relatively high, and pH was depressed. Turbidity and suspended solids concentrations were relatively high due to fine sediment contribution from the tailings (see Appendix B). Cabin Creek is currently a 303(d)-listed impaired waterbody (Alaska ID: 40501-001) for manganese from the Nabesna Mine. The NPS and Alaska Department of Environmental Conservation staff visited the impacted waterbody in 1997 to discuss specifics of a recovery plan with the owner of the Nabesna Mine property. Recovery plan objectives include increasing the low pH of the acidic tailings, revegetating the tailings with indigenous species, and re-construction of the existing drainage ditches around the tailings to divert stormwater runoff away from Cabin Creek (U.S. Environmental Protection Agency, 2003). WRST is currently working with the National Park Service's Water Resources Division and Geological Resources Division to further address this water quality issue.
>
> *Jack Creek*: a non-glacial biologically productive stream with very little physical channel or riparian disturbance except along an access road to a private inholding on Jack Lake and at a few off-road vehicle crossings. In 1986, total recoverable metals, turbidity and suspended solids concentrations were low in Jack Creek upstream of where Cabin Creek enters the stream (see Appendix B). The lower reach of the creek was not sampled. Primary productivity and aquatic macroinvertebrates were found to be abundant in the creek.

<u>Chisana and Gold Hill (located in northeastern WRST)</u>

Most of the streams in the Chisana and Gold Hill study area are non-glacial. Only Chavolda (Wilson) and Chathenda (Johnson) creeks are influenced by glaciers in their headwaters.

Big Eldorado Creek: a small clear water stream with an average flow of approximately 10 cfs recorded near the mouth in 1987. The stream morphology and riparian habitat have been disturbed for most of the stream length. Early mining involved diverting and ditching the creek. Remnants of dams along the stream course and intact diversion ditches remain today. Stream gravels have been sorted and staged along the stream with an access trail that parallels the stream channel. The existing chemical conditions (pH, conductivity, alkalinity, and dissolved oxygen) were found to be in an acceptable range in 1987 (see Appendix B). Physical habitat loss and stream obstructions are likely the reasons fish are not present in this creek.

Gold Run Creek: a small clear water stream where ground sluicing, booming, dredging and drift mining were common mining practices on the creek in the past. Nine dams remain intact in Gold Run Creek from past mining activities. The water quality in 1987 (pH, dissolved oxygen, alkalinity, hardness and conductivity) was found to be within an acceptable range for the survival of aquatic life. Total recoverable metals concentrations were below the detection limits (see Appendix B). Physical habitat loss and stream obstructions are likely the reasons fish were not present in this creek in 1987.

Little Eldorado Creek: a small clear water stream that has been extensively mined since the early 1900s. Stream gravels have been sorted and piled along the stream banks, and riparian habitat has been disturbed for most of the stream length. Dissolved oxygen, pH, alkalinity, hardness and conductivity in Little Eldorado Creek were within acceptable limits for the survival of aquatic life in 1987. Total recoverable metal concentrations were below the detection limits. Turbidity and suspended solids were low due to the low flow conditions of the creek at the time of sampling (see Appendix B). Increases in both parameters occur during high-flow conditions due to the runoff from naturally unvegetated headwaters and 18 acres of mining disturbance along the stream. Fish were not observed in the creek in 1986 or 1987, but may have occurred before the physical habitat was substantially altered.

Skookum Creek: a small (average flow at mouth < 2 cfs) clear water tributary to Little Eldorado Creek that has been mined heavily in the past. Dams were used in the past and dam sections still exist instream. A 6-foot floodgate and flume remain were intact in 1987 on the upper portion of the creek. Due to past mining activities, there was a progressive shift of the streambed to the north and overall gradient of the stream increased.

Wooden planks were placed in the stream to channelize the stream and in 1987, the upper channel of Skookum Creek was still defined by wooden planks. Tailing piles remain in and along the stream. Water was a limited resource for miners, so water was diverted via ditches from other streams to Skookum Creek. Dissolved oxygen, pH, alkalinity, hardness and conductivity in Skookum Creek were within acceptable limits for aquatic life. Total recoverable metals were either below EPA standards or below detection limits in 1987 (see Appendix B). Turbidity and suspended solids were found to be low in the creek, but increases in both parameters would be expected during high-flow conditions due to the six acres of disturbance in the watershed. Fish were not observed in Skookum Creek in 1986 and 1987, likely due to the substantial alterations in the channel and gradient, along with the instream obstructions.

Bonanza Creek: a clear water stream with an average flow of 20 cfs at the mouth recorded during the 1987 sampling event. Extensive mining operations have occurred on Bonanza Creek since the early 1900s. Splash dam ruins remain in the stream today. In the early 1900s, a major flume system was constructed that diverted the creek waters from the channel. A portion of this deteriorated system still runs along the northwest bank of Bonanza Creek. Water quality conditions (pH, conductivity, alkalinity, hardness, dissolved oxygen) were found to be within an acceptable range for survival of aquatic life in 1987. Total recoverable metals measured in 1987 were below the detection limits, with the exception of manganese, which was still at safe concentrations (see Appendix B). Suspended solids and turbidity were low, but storm runoff from 30 acres of disturbed area in the drainage basin can increase the sediment loading, elevating these, and likely other water quality parameters. Aquatic invertebrates were present in Bonanza Creek in both the headwaters and mouth in 1986. No fish were observed in 1986 or 1987.

<u>Nizina (central WRST)</u>

Both glacial and non-glacial streams occur in the Nizina study area. Tundra ponds occur at lower elevations in the western portion of the area. Ground water is high in iron.

Chititu Creek: a glacial-fed stream with an average flow of 300-400 cfs at the mouth (USGS 1972-1983 data). The creek experienced heavy mining in the past, where the entire stream was diverted to a side channel at one time. Today, dam remnants can be found along the creek with tailing and gravel piles still present. A road runs along the left bank and riparian vegetation has been disturbed. Chititu Creek is naturally turbid in the summer months due to its glacial origins. At low flow in 1986, total recoverable metal concentrations were below detection limits; however, at high flows in the same season, total copper, iron and zinc were measured at concentrations exceeding EPA standards for aquatic life (see Appendix B). Aquatic invertebrates were found in low densities in Chititu Creek in 1985 and 1986. Although fish are not known to reside in the creek, the lower sections are thought to be used as a migratory route.

Rex Creek: a glacial-fed stream where nearly the entire stream has been disturbed due to mining-related activities. Remnants of a 40-foot dam in the headwaters and water diversion ditches exist today. Rex Creek runs slightly turbid due to a small headwaters glacier. Dissolved oxygen, pH, hardness, and conductivity were found to be within an acceptable range for survival of aquatic life in 1986. Total recoverable metals were below the detection limits in both the headwaters and near the mouth (see Appendix B). Aquatic invertebrates, including flatworms and zooplankton, occur in the upper portion of Rex Creek. Fish were not observed in the creek from 1985-1987.

Dan Creek: is a glacial-fed stream, which has been continuously mined since 1901. Hydraulic mining was used on the creek for 25 years and dams were commonly constructed in early mining practices. Major water diversions were common over the years. Dan Creek has a history of flooding that included extensive property loss. The creek carries a heavy suspended sediment load during the warm summer months due to glacial meltwater (see Appendix B). Extensive disturbance from past mining activities also contributes to suspended sediments from nonpoint runoff. Dirt roads between Dan Creek and May Creek and between Dan Creek and Spruce Point present another source of nonpoint loading. The reported total recoverable copper, iron and zinc were at concentrations exceeding EPA standards for protection of aquatic life in 1986 (see Appendix B). The creek does not support fish populations.

<u>Kennecott (central WRST)</u>

Most of the tributaries in the Kennecott study area are clear water streams, with the major drainages in the area (McCarthy Creek and Kennicott River) glacially fed.

Kennicott River: a glacial-fed river with several non-glacial streams (Amazon, Jumbo, Bonanza and National creeks) that drain into the headwaters of the Kennicott River. All four of these tributary streams have been disturbed since 1911 by access roads, dams, and activities associated with hardrock mining. Stream diversions, obstructions, and changes in stream morphology exist in these drainages. Total recoverable metals measured in National and Bonanza creeks in 1986 were below the detection limits, except for zinc in National Creek, which exceeded the EPA chronic toxicity standard (see Appendix B). Algae and aquatic invertebrates were observed in the lower reaches of these streams. It should be noted that National and Bonanza creeks are important potable water sources for WRST and private inholdings in the Kennecott area.

McCarthy Creek: a glacial-fed creek that originates from the McCarthy Glacier and drains the eastern portion of the Kennecott area. Placer mining, drift mining and access routes have disturbed the McCarthy Creek drainage. In 1986, total recoverable copper, zinc and iron concentrations exceeded EPA standards for protection of aquatic life (see Appendix B). Aquatic invertebrates and algae were observed in the upper and lower portions of McCarthy Creek during the 1986 sampling. Nikolai Creek is a clear water tributary to McCarthy Creek. Activities in this drainage were related to the development of a hardrock copper mine. Suspended solids and turbidity were low in Nikolai Creek during the 1986 sampling; however, total recoverable zinc was 2 mg/L (see Appendix B).

The groundwater in WRST typically has high concentrations of metals, particularly iron, due to its long contact with highly mineralized surfaces. Dissolved solids may be higher where groundwater circulation is restricted by permafrost. Some groundwater in the park/preserve is saline, due to underlying marine sedimentary deposits, which contribute chloride and sodium (National Park Service, 1990a).

Air Quality

The NPS is responsible to preserve, protect and enhance air quality and related values of the National Park System units under both the Organic Act (16 U.S.C. 1, 1a-1) and the Clean Air Act. WRST is designated Class II under the Clean Air Act, the second most stringent air quality standards. WRST lacks quantitative baseline information on existing air quality levels and sources of pollution. The nearest air quality monitoring stations are Anchorage, Fairbanks, and Valdez. Therefore, it is unknown if present air quality complies with the Class II standards (National Park Service, 1998a).

A NPS project was initiated in 2002, “Western Airborne Contaminants Assessment Project”, to determine the risk to ecosystems and food webs in western national parks from the long-range transport of airborne contaminants. It has been designed and implemented by the National Parks Service’s Air Resource Division in cooperation with national parks, the Environmental Protection Agency, the U.S. Geological Survey, and several universities (National Park Service, 2002a). The contaminants of concern are compounds and elements known as Persistent Bioaccumulative Toxics (PBTs). This group contains a variety of persistent organic pollutants (POPs) such as PCB, DDT, and HCH; as well as elements such as mercury (Hg). These materials are direct or indirect products of human industrial activity and can be transported thousands of miles in the atmosphere. The project design centers around six national parks in the west (Noatak, Denali, Glacier, Olympic, Rocky Mountain, and Kings Canyon) representing a latitudinal gradient as well as a coastal to interior gradient. If additional funding is available, a smaller subset of samples will be taken at 13 other NPS units, including WRST, if these park units can provide transportation and staff to complement the sampling efforts (Blett, pers. comm., 2003).

Biological Resources

Water resources are especially important to the success of WRST's flora and fauna. Biological resources can also serve as a tool for better understanding hydrological systems. For example, botanical evidence can assist with determining recent history of glaciers. Biological integrity can indicate environmental condition and ecological health of water resources.

Since a comprehensive evaluation of biological resources extends beyond this report, the following two sections concentrate on park biological resources that are influenced by water resources or federally-listed as threatened, endangered, or candidate species, and state-listed as endangered or species of special concern. Along with providing some basic background information, the purpose of this section is to begin exposing some of the biological concerns that might serve as indicators to water-related issues.

<u>Flora</u>

Because of the wide range of climatic zones and elevations, WRST contains a wide variety of ecosystem types including those of both coastal and interior regions and gradations between the two (U.S. Department of the Interior, 1974).

Alpine tundra is found at elevations between 3,000 and 5,000 feet. Dry tundra, consisting mostly of low, matted alpine plants dominated by mountain avens, is found on the steeper mountain slopes and exposed ridges. Wet or moist tundra, consisting of sedges and grasses interspersed with low shrubs, occurs on the lower more gradual slopes. White spruce thrive along the river bottoms. A representative virgin stand of white spruce in the Chitina Valley has been designated as a natural area by the Society of American Foresters. White spruce is also mixed with birch, balsam poplar, and aspen on upland sites. Forests along the coast consist of large Sitka spruce and Western hemlock (National Park Service, 1986).

In the extensive flat and gently rolling terrain around the Wrangells are large areas of open forest consisting primarily of black spruce with an occasional tamarack and paper birch. These slow-growth forests usually have a continuous shrub layer in depressions and a thick moss layer on the open forest floor. This forest occurs on permafrost soils (National Park Service, 1986).

Dense stands of tall willows are usually found along the riparian areas of streams. Dense alder thickets cover large areas on steep hillsides, especially where avalanches are frequent. Open thickets of resin birch are in the zone between the forest and alpine environments (National Park Service, 1986).
An inventory of the vascular flora of the park was initiated in 1994. The objectives of the inventory were to:

- develop an understanding of the history, genetic diversity and biogeography of the park's flora, an area poorly understood floristically because of its remoteness;
- conduct inventories of the vascular flora of selected areas within the park;
- identify populations of rare taxa, unique floristic associations and areas of phytogeographic interest which the park may need to protect;
- establish a database of all plants known to occur in the park and maintain information on the rarity, distribution, synonymy, taxonomy and collections of these plants;
- prepare a voucher collection of all plants known to occur in the park, and
- provide the structure for an ongoing assessment of the park's flora.

Site selection focused on unique landforms and lithologies, areas with no previous botanical collections and areas known to have rare or endemic taxa. The survey was also limited to north of the Bagley Icefield due to the cost of accessing the coastal regions.

7000 voucher specimens were collected from 260 sites in three field seasons. WRST's collection history has been included in the park's database. In addition, collections have been georeferened by park staff prior to this inventory. Results of the three-year inventory indicate that the flora of the park is extremely diverse, especially for a subarctic region. Some of the more significant findings are (National Park Service, 2003):

- 11 species new to the flora of Alaska;
- 17 occurrences of three U.S. Fish and Wildlife Service Species of Concern;
- 362 occurrences of 69 Alaska Natural Heritage Program rare plants;
- 30 Alaska-Yukon endemics;
- 52 significant range extensions (new to south-central Alaska and greater than 200 km from previous collections), and
- the identification of areas of high endemism and of previously undescribed plant communities.

One notable find from this study was a new location in the park of a globally rare endemic, *Cryptantha shackletteana* (Boraginaceae), Shacklette's cryptantha. This plant is a U.S. Fish and Wildlife Service Species of Concern and is ranked by the Alaska Natural Heritage Program as critically imperiled in the state. Previously, it was known from the type locality at Eagle, Alaska and one other site in close proximity on the Yukon River. The new location in the park extends the range of this species into the Alaska Range. Several localities of *Montia bostockii*, a species nominated for listing as threatened on the Federal Threatened and Endangered Species list has also been identified in WRST (National Park Service, 1998a).

<u>Fauna</u>

The National Park Service is mandated by ANILCA and other laws to protect the habitat for, and populations of, fish and wildlife within the park and preserve (ANILCA, sec 201(9) and 16USC, sec. 1) (National Park Service, 1986). The National Park Service and the state of Alaska work cooperatively to manage the fish and wildlife resources of WRST. The Alaska Department of Fish and Game, under the constitution, laws and regulations of the state of Alaska, is responsible for the management of the fish and wildlife resources of the state. Within conservation units, such as WRST, state management of fish and wildlife resources is required to be consistent with the provisions of ANILCA, therefore, some aspects of state management may not apply with WRST (National Park Service, 1986).

The diversity of vegetation has produced equally diverse wildlife populations. Wildlife species identified as significant contributors to park values include brown/grizzly bears, black bear, moose, caribou, wolf, trumpeter swans, bald and golden eagles, Dall sheep and mountain goats. Harbor seals and Stellar sea lions inhabit the coast along the Malaspina Forelands and Icy Bay. WRST's coastal waters are frequented by whales and other marine mammals (National Park Service, 1998a).

Mammals

The Steller sea lion (*Eumetopias jubatus*) is a federally-listed threatened species that inhabits the Gulf of Alaska coastline. The Steller sea lion is listed by the state as a species of special concern. Steller sea lions have declined dramatically throughout the Gulf of Alaska and Bering Sea during recent decades (National Park Service, 1994a). Sease and Loughlin (1999) documented a 53% decline of adult and juvenile (non-pup) Steller sea lions for the central Gulf of Alaska during June and July aerial surveys from 1990 to 1998. WRST's coast also provides important habitat to harbor seals as breeding and feeding grounds. Harbor seals may be experiencing the same declines but no data are available (National Park Service, 1998a).

There are also seven whales federally-listed as endangered species that occupy Alaska waters. These are the northern right whale (*Balaena glacialis*), bowhead whale (*Balaena mysticetus*), sei whale (*Balaenoptera borealis*), blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*) and sperm whale (*Physeter macrocephalus*). The humpback, northern right, and blue whales are also state-listed endangered species. The beluga whale (*Balaena mysticetus*), specifically the Cook Inlet population, is listed by the state as a species of special concern. Beluga whales use the Grand Wash Slough in WRST, but the extent or habits of their use is not known (National Park Service, 1986).

Birds

The trumpeter swan (*Olor buccinator*) was once considered to be a threatened species by the U.S. Fish and Wildlife Service but was removed from the list on the basis of surveys showing large numbers of swans in the region. One of the numerous prime nesting areas used by swans is at the mouth of the Bremner River in the park. Bald eagles (*Haliaectus leucocephalus*) and golden eagles (*Aquila chrysaetos*) nest along rivers in WRST, with a concentration of nesting occurring along the Chitina River. Waterfowl nest in extensive lowland areas along the area's rivers and lakes, and seabirds are common in coastal areas.

The Malaspina forelands and Copper River are migratory bird flyways (National Park Service, 1986).

Of the five listed threatened and endangered species in Alaska, only the American peregrine falcon (*Falco peregrinus anatum*) may be found in WRST. They are known to migrate through the area, but there is no recorded nesting by peregrines in the park/preserve (National Park Service, 1986).

It should be noted that more than seven thousand sea bird carcasses were recovered from Alaska's coast at Katmai National Park following the *Exxon Valdez* oil spill (National Park Service, 1994b). This provides a graphic example of a water resource impact extending to biological communities in the region.

Fish

Fish in WRST are not abundant, with the exception of lake populations and the Copper River salmon runs. The number of populations and population abundance are limited due to naturally harsh stream conditions including high gradient, torrential seasonal flows, high velocities, cold temperatures, high sediment loads, low biomass of prey organisms, and winter freeze conditions. Under harsh conditions such as these, natural mortality and slow growth limit the number of fish occurring in WRST waters. The clear water streams that originate in WRST serve an important function in perpetuating local fish populations (National Park Service, 1990a).

In the Copper River drainage, lakes along the Chitina-McCarthy Road contain Dolly Varden (*Salvelinus malma*), sockeye salmon (*Oncorhynchus nerka*), coho salmon (*Oncorhynchus kisutch*), grayling (*Thymallus arcticus*), lake trout (*Salvelinus namaycush*), and burbot (*Lota lota*). The Alaska Department of Game and Fish stock fish in Van, Sculpin, and Streina lakes. Along the Nabesna Road, there are several lakes that provide recreational angling for grayling, burbot, and lake trout. Rainbow trout (*Salvelinus fontinalis*) are stocked in Rock Lake. Cooper and Tanada lakes provide recreational angling for lake trout, burbot, grayling, and anadromous sockeye salmon. In addition, a significant natural kokanee population exists in Copper Lake, though not common or abundant elsewhere in Alaska. Tanada Creek has a small population of king salmon (National Park Service, 1986).

Within the Yukon/Tanada watershed, fisheries surveys and research have not yet been completed. The following systems and lakes are known to contain fish species: Chum salmon are present in the Chisana River downstream of Sheep Creek, and chum salmon spawning areas occur just downstream of the confluence of Sheep Creek. Lake trout are recorded in Beaver Lake, Beaver Creek, Ptarmigan Lake, Ptarmigan Creek, and Rock Lake (National Park Service, 1986).

WATER RESOURCE ISSUES

The park's water-related issues presented in this section were identified during a 10-day information-gathering effort in WRST and Anchorage by the author. Along with a technical literature review, information sources included interviews with NPS management and other federal and state agencies.

Baseline Inventory and Monitoring

To effectively manage natural resources, inventory and monitoring activities should integrate into the overall natural resources planning and management process. Information obtained from these activities better assists the NPS toward understanding how the various environments in a park unit function naturally, and help isolate anthropogenic changes.

With its large landmass, low population, and limited resource development, relatively little is known about Alaska's water resources, including WRST. The U.S. Geological Survey has calculated that Alaska in 1995 had an average of one stream gaging station per 8,395 square miles, compared to an average of one gage per 336 square miles in the lower 48 states (Bayha et al., 1997). The National Weather Service rain gage network in Alaska is about one-tenth that of the lower-48 states. Because of the inherent interdependency of precipitation, flow, and water quality to provide an accurate picture of water resources, cooperation among various federal and state agencies in Alaska has been and will continue to be of utmost importance to the NPS (Deschu, 2000).

In 1990, an Aquatic Resources Inventory and Monitoring Workshop was held in Chena Hot Springs, Alaska with resource managers from Alaskan parks. The following is a summary of suggestions presented during this meeting:

1. Goal for Inventory and Monitoring: to develop a meaningful database to assess the status and variation of representative aquatic resources in Alaskan parks.
2. Inventory: A synoptic survey of aquatic resources is required prior to implementing a monitoring program. Park units should be divided into sub-units based on common environments with surveys conducted for each sub-unit.
3. Monitoring: Project design should be based on regional objectives and specific park concerns, interests, and objectives. Quantitative sampling at several trophic levels is essential, unless there is a need to focus on a specific resource.
4. Methods: Standardization and documentation of methods is essential, especially for region-wide assessments of status and variation.

An inventory of water resources is needed at WRST. Methods should be designed to meet or exceed servicewide standards for Level I water resource and water quality inventories (National Park Service, 1999a). Baseline characteristics such as bathymetry and basic water chemistry profiles need to be collected on lakes. River discharge, length, gradient, and chemistry are needed on rivers. From this basic field information and supplemental GIS analysis, water resources could be stratified to building effective monitoring programs for park waters.

The NPS Water Resources Division is in the process of preparing a comprehensive summary of existing surface-water quality data for WRST, *Baseline Water Quality Inventory and Analysis, Wrangell – St. Elias National Park and Preserve*. This effort requires strong assistance by WRST staff. Once completed, the report will include data retrievals, with some data analysis, from six EPA national databases (i.e., STORET).

As described earlier in this report, the NPS Alaska Regional Office has prepared an ecological unit map, including descriptions (National Park Service, 2001a), to aid sampling for inventory and monitoring studies in WRST. One useful strategy is to stratify sampling by ecosystem regions to ensure adequate coverage of all ecosystems in the park and preserve. The descriptions for the eight *Ecosystem Regions* and 64 *Ecological Subsections* (see Appendix A) identified in WRST are an important information source for NPS staff and others to reference, as needed.

The U.S. Geological Survey, in cooperation with the National Park Service, conducted research related to air quality impacts on biological resources in and around WRST in the early 1990's (Crock et al., 1993). These studies focused on the use of moss, lichen, and spruce as biomonitors of the emissions from a proposed 10 MW coal-fired power plant. By determining the metal concentrations in these species, it is possible to map the spatial distribution of the zone of influence of airborne sulfur or metals from a point source. All sites were marked, mapped, and photographed and geographical coordinates were recorded. These baseline data are available, as needed.

The U.S. Environmental Protection Agency (EPA) has endorsed the use of biological integrity as indicators of environmental condition and ecological health. It is unique among currently used indicators in that 1) they use information collected directly from the aquatic organisms and their surrounding biological community, 2) the biota are shaped by all environmental factors to which they are exposed over time, whether chemical, physical, or biological, and 3) they combine multiple, community-level, biological response characteristics into an indicator of cumulative environmental impacts (Karr 1991, 1993). The Alaska Department of Environmental Conservation initiated two pilot bioassessment projects in southeastern Alaska, Admiralty Island and Prince of Wales Island. The objective of these two projects is to evaluate EPA's Rapid Bioassessment Protocols for use in Alaska (Davis et al., 1996). The Rapid Bioassessment Protocols were designed as relatively inexpensive screening tools for determining if aquatic environments were supporting unimpaired biological communities (Plafkin et al., 1989). These protocols are essentially a synthesis of existing methods that have been employed by various state water resource agencies (Barbour et al., 1999). EPA has also developed a set of protocols for biological assessment of lakes and reservoirs relevant to issues of ecological integrity, which may be applicable for WRST (U.S. Environmental Protection Agency, 1998). The University of Alaska Anchorage's Environment and Natural Resources Institute (ENRI) has been instrumental in developing a biological monitoring program for Alaska (University of Alaska Anchorage, 2003).

The National Hydrography Dataset (NHD) is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells. Although the NHD has been completed for Alaska, BLM is currently cleaning up the data (Deschu, pers. comm., 2003). Within the NHD, surface water features are combined to form "reaches", which provide the framework for linking water-related data to the NHD surface water drainage network. The NHD is based upon the content of USGS Digital Line Graph (DLG) hydrography data integrated with reach-related information from the EPA Reach File Version 3 (RF3). While initially based on 1:100,000-scale data, the NHD is designed to incorporate and encourage the development of higher resolution data required by many users (U.S. Geological Survey, 2003).

WRST has numerous rivers influenced by glacial melt runoff. Very little is known about the role these systems play in the ecosystem or how to monitor them during seasonal cycles. A common perception is that they are silt-laden streams with little to offer and therefore they have not received the credibility that "pristine" clear water bodies have in support of associated ecosystems. An inventory and monitoring program of these water resources is needed. Specific study locations and scientifically valid monitoring protocols (quality and quantity) for these water resources within the park have not been identified. Information gathered through implementation of an inventory and monitoring program would be used to determine how the water resources influence the ecosystem and are effected by changes (anthropogenic, climatic, and natural) (National Park Service, 1998a). Many of the stream gages are far enough downstream from their glacial sources that the influences of the glaciers cannot be determined with accuracy. Therefore, new river gaging stations should include sites closer to the glaciers. These stations are required for precision-level studies of glacier snow, ice, and water balances (Mayo, 1991).

Baseline data on anthropogenic influences in WRST could integrate into the park's management of natural resources. The park needs additional staff qualified to collect data and develop and implement a method to process this data that results in quantifying land use trends and anthropogenic pressures. This information would ultimately assist in evaluating land use effects on water resources and assure regulatory controls are in place to protect water quality and other environmental indicators.

WRST is located in the Central Alaska Inventory and Monitoring Network, which is one of 12 networks (32 total networks) currently funded (beginning in 2001) through the NPS Natural Resource Challenge to design and implement a water quality monitoring program. This program is to be fully integrated with the network-based Park Vital Signs Monitoring Program. The overall objective of the water quality component of the Vital Signs program is to improve the quality of impaired waters and to maintain the quality of pristine waters in parks. Maggie MacCluskie is the Central Alaska Network Coordinator, who is working with Nancy Deschu (NPS-Alaska System Support Office) and Molly McCormick (WRST).

Inventory and monitoring programs for natural resources in the park assist both state and federal agencies with various management elements. This is especially important with subsistence management. Since 1990, the federal government has assumed responsibility for subsistence game management on federal lands. In 1999, the federal government also assumed management of subsistence fisheries on 243 million acres of federal land in Alaska, including WRST (Worl, 1999). Subsequently, WRST is now challenged with managing salmon fishery resources for rural subsistence priority within the park. The Federal Subsistence Management program involves the following five federal agencies; U.S. Fish and Wildlife Service (lead agency), National Park Service, Bureau of Land Management, Bureau of Indian Affairs, and USDA Forest Service. Increasing numbers of recreational users in the backcountry as well as in developed areas of WRST have increased the potential for conflicts between consumptive and nonconsumptive users. ANILCA identifies specific activities related to subsistence that require NPS participation. Specific subsistence management activities that need to be continued or implemented at WRST include population and harvest monitoring studies, determination of the eligibility dates of rural residents, administration of backcountry access permits, and limitations on subsistence activities, if necessary, and review of park programs for compliance [National Park Service (1994b), National Park Service (1999b)].

Climate Change and Influence on Water Resources

One of the more significant natural resource issues in Alaska is climate change (Nelson, pers. comm., 1998). Paleoclimatologists have used proxy data (i.e., ice cores, tree rings, etc.) to reconstruct the earth's historical climate. These data have resulted in remarkable discoveries, including the fact that climate has fluctuated dramatically in the past and the global mean temperature has risen approximately 1 degree Fahrenheit on average the past 100 years [Trenberth (1997), Rouse et al. (1997)]. Northern hemisphere spring and summer snow cover, monitored by satellite imagery since 1973, decreased by 10% between 1987 and 1997 (Trenberth, 1997). Trying to define the source(s) for climate change has produced varied explanations from natural causes to human-induced impacts (i.e., burning fossil fuels, deforestation, etc.). Most of the scientific community believes the climate change we are currently experiencing is primarily human-induced. The burning of fossil fuels alters the balance of radiation on Earth through both visible particulate pollution (called aerosols) and gases that change the composition of the atmosphere. The latter are referred to as "greenhouse gases" because they are relatively transparent to incoming solar radiation, while they absorb and reemit outgoing infrared radiation, thus creating a blanketing effect that results in warming.

Pinney and Begét (1991) reported that rapid environmental changes and glacial fluctuations on the Alaska Peninsula might be in response to transient changes in the concentration of atmospheric greenhouse gases and solar intensity. Changes in moisture supply and thermal regime could alter topography and vegetation, which in turn could alter the water surfaces of northern peatlands and thus alter the natural delivery of CO_2 and CH_4 from surface waters to the atmosphere (Rouse et al., 1997). Increases in temperature can also extend ice-free seasons which will usually lead to increases in the ratio of evaporation + evapotranspiration to precipitation, resulting in less water found in the landscape (Schindler, 1997). Overall, increased glacial runoff from global warming may have a significant influence on stream flow, temperature, and sediment regimes. Changes in stream temperatures may eliminate certain invertebrate species or increase the length life cycles. Salmonid development rates in terms of egg incubation, fry emergence, and growth, and time of smoltification could be altered.

Because of the scarcity of real-time records, many regional climate summaries have relied heavily on modeled predictions, which are themselves of questionable validity (Schindler, 1997). Basic research and long-term monitoring are needed to compliment on-going regional and global efforts to better understand the causes and consequences of climate change.

Glaciers are identified internationally as a critical place to look for early signs of global change because they are known to be sensitive to climate variations on a seasonal and yearly basis. The extent of glaciation, ideal climatic location, and glacier variability in WRST make it one, if not the highest priority site within North America for conducting investigations of climate and glacier interactions. WRST is located along a major storm center tract, the “Aleutian Low”. The WRST climate and glaciers are in a complex of upslope and downslope regions where atmospheric moisture is progressively released as rain and snowfall. Thus, each range serves as a partial precipitation barrier and the equilibrium line altitudes of glaciers increase away from the moisture source. One cannot expect the relationship between climate and glaciers to be the same in each of these regions, so a network of a few carefully-selected study glaciers is warranted (Mayo, 1991). There is a strong consensus among scientists on the need for climate and glacier mass balance information in WRST.

Monitoring of glaciers in the St. Elias Mountains of Alaska can promote understanding of the links between climatic variables and glacier behavior in this area of North America that is the core of the present glaciation and has not been studied. Other important questions remain about the distribution and frequency of glacier surges, geologic influences, and the behavior to tidewater glaciers (Mayo, 1991). Mayo and Trabant (1984) suggested an increase in air temperature might result in an increase in the overall snow and ice balance of glaciers in the maritime coastal area of south-central Alaska. The capacity for warmer air masses to transport water vapor from the ocean leads to greater deposition of snow on the windward side of the mountain ranges near the ocean. Today, we see the Hubbard Glacier advancing along WRST’s coast, creating some hydrological hazards discussed later in this report.

WRST has developed a project statement (*Project Statement:WRST N203.00)* for expanding the present remote weather station (RAWS). The objective is to identify strategic locations for automatic weather stations within WRST’s boundary, in cooperation with the National Weather Service. Climatological stations are essential for interpretations of glacier mass balances. Existing coastal climatological sites (e.g., Yakutat, Cordova, and Seward) sample the same weather that affects glaciers near the Gulf of Alaska and could be included in WRST’s climatological network (Mayo, 1991).

Locations where climatological data are being collected by the National Oceanic and Atmospheric Administration (NOAA) and the Federal Aviation Agency (FAA) in and around WRST include: Northway, Slana, McCarthy, Edgerton Highway, Gulkana, Nabesna, Valdez, Cordova, and Yakutat. During the fire season, the Alaska Department of Natural Resources collects fire weather data at Chistochina, Tazlina Lodge, Chitina, and Kenny Lake. Only the Nabesna and McCarthy sites are within WRST's boundary. There are six snow survey sites within WRST's boundary (May Creek, Chokosna, Dadina Lake, Sanford River, Lost Creek, and Chisana), with six survey sites located just outside the park boundary (Kenny Lake School, Tolsana Creek, Chistochina, Mentasta Pass, Jatahmund Lake, and Paradise Hill). High quality data is collected at some sites; however, data quality suffers due to irregularity of data collection and site location. Climatological information that is currently available is of limited use and probably does not accurately reflect conditions within WRST. The long-term task is to establish four or five climate stations in WRST, which record temperature, total precipitation, and snow fall (National Park Service, 1998a). Long-term automatic weather stations near the equilibrium altitude of the main glaciers on the north side of the Bagley Icefield and the south and north sides of the Wrangell Mountains are warranted. The Bagley Icefield station should have the highest priority because it would sample climate where the largest expanse of glaciers occur (Mayo, 1991).

According to Mayo (1991), at a reconnaissance level, highly useful information can come from a single observation site near a glacier's equilibrium line. Mass balance and flow are relatively easy to monitor there because the snow is not as deep and the summer melt is not as large. A glacier's time lag for flow and ice thickness responses to climatic variations are minimal at the equilibrium line. There is also a need to obtain "ground truth" information near glacier equilibrium lines in support of current research in remote sensing. Thus, any glacier study should start there and the highest quality of long-term observations should be maintained there to understand the long-term influences of climate on the behavior of glaciers. At least three geodetic control stations are needed to support observations at each site. As the observation program grows, additional mass balance or other measurement sites should be established on these glaciers, enhancing our ability to understand the behavior of the entire glacier.

A transect extending from the coast to the interior that includes the Bering Glacier, Bagley Icefield, Tana Glacier, Kennicott Glacier and Nabesna Glacier has been identified for conducting research and monitoring (National Park Service, 1998a). WRST needs to establish the foundation for implementing a viable climate-glacial monitoring and research program, through cooperative efforts, that includes developing bibliographies and analysis of existing data (*Project Statement: WRST N401.00*).

WRST is looking to obtain funding for a cooperative study between the NPS and Lamont-Doherty Earth Observatory Tree Ring Laboratory. The goal is to identify and sample trees buried and preserved by tephra deposits and old growth stands, which can provide a source of paleoclimate data (Project Statement: WRST N700.00).

As introduced earlier in this report, small lakes and ponds in WRST have changed dramatically since the 1950's. Many of these lakes and ponds no longer contain water or are greatly reduced in size (Figure 5). Climate change may be responsible for the dramatic lake changes and indicate future pressures on WRST's ecology. The effects on species populations dependent on these waterbodies is unknown. Lake and pond ecosystems are an integral component to the park and preserve. Many bird and fish populations use or reside in these lakes and ponds. WRST has prepared a proposal (*Project Statement: WRST N309.00*) that would 1.) calculate the change in small lake and pond surface area in the lower Copper and Chitina River Valley between the late 1950's and the late 1990's, 2.) classify these waterbodies and determine if the changes are limited to a lake type(s), 3.) core a few lakes in the different classes, 4.) identify which of the small lake and pond systems are changing the most, and 5.) develop a plan to broaden the classification of these waterbodies and the effects of species populations dependent on these small lakes and ponds.

Figure 5. Some of the areas at Wrangell-St. Elias National Park and Preserve where ponds and lakes have recently disappeared.

Fisheries

The Copper River drainage is the focal point of fisheries in WRST, providing spawning habitat for over 124 stocks of sockeye salmon (*O. nerka*). Significant numbers of adult salmon are harvested in commercial drift gillnet operations near the mouth of the Copper River from mid-May to September. Salmon escapement into the Upper Copper River system contributes to subsistence, personal use and sport fishing throughout the summer. The monitoring and evaluation of these runs is essential towards developing harvest management strategies that meet the mandates of the Alaska National Interest Lands Conservation Act (ANILCA). Subsistence uses are permitted on public lands where such activities have been traditional and have priority over the taking of fish for other purposes (ANILCA sec 201(9) and ANILCA sec. 804) (Raeder et al., 1998).

A subsistence fishery occurs from the community of Slana downstream to the Chitina-McCarthy Bridge. A subsistence fishery also occurs in the river's headwaters at the confluence of the Copper River and Tanada Creek. The area of the river from the Chitina-McCarthy Bridge downstream to a marker immediately upstream from Haley Creek supports Alaska's largest personal use fishery. In the Copper River Delta, a commercial fishery harvests sockeye and king salmon of Copper River origin (National Park Service, 1999a).

Most fisheries in the Copper River drainage are interrelated and regulations and management actions in one fishery may affect other fisheries. This is most evident in anadromous salmon fisheries when a given stock is harvested at different times in different fisheries along the stock's migratory route. For example, actions taken in the Copper River Delta sockeye and chinook salmon commercial fishery will affect the Copper River subsistence, personal use dip net and the Copper River's tributary sport fisheries for these species (National Park Service, 1999a). The annual salmon runs also define the spatial distribution of WRST's fish and wildlife consumers, their nutritional status, and ultimately their reproductive success and abundance. Spawning runs of fish produce nutrients to streams and lakes by excretion, release of gametes, and their own mortality (Allan, 1995). An example is found in a report by Richey et al. (1975) who identified a phosphate peak following the die-off of kokanee salmon (*O. nerka*) in a small tributary in Lake Tahoe, California. In Sashin Creek, Alaska, isotope analysis showed that nitrogen and carbon derived from a spawning run of Pacific salmon (*Oncorhynchus spp.*) were incorporated into periphyton, macroinvertebrates, and fish (Kline et al., 1990). More recently, scientific research suggest that these "salmon-derived nutrient" subsidies may have significant impacts on both freshwater and riparian communities and on the life histories of organisms that live there (Willson et al., 1998, Cederholm et al., 1999)

Existing fishing regulations and fishery management do not adequately protect two sockeye salmon stocks that spawn in Tanada Creek within WRST. Currently no limit exists for the number of sockeye salmon that can be harvested within either the commercial or subsistence fisheries that target these stocks. Fishery monitoring data collected from weir projects conducted by the Alaska Department of Fish and Game in 1975, 1978, 1979 and the National Park Service in 1997, 1998, and 2001 indicate that abundance and timing of the sockeye run in Tanada Creek is highly variable in both abundance (1600 – 29,000) and return timing. Variations in the runs could be attributed to variations in productivity in Tanada Lake, to a disproportionate harvest in the commercial and subsistence fisheries downstream, to unknown variables affecting the ocean survival, to problems with passage for outmigrants (severe drought or flooding), or to natural variations in stocks. Correlations between lake productivity, which includes water quality, macrozooplankton density and biomass, and juvenile sockeye growth and survival have been clearly established [Nelson (1958), Koenings and Burkett (1987)]. Understanding the effect of natural fluctuations in water quality and productivity in

Tanada Lake on adult sockeye salmon returns is crucial to establishing a natural and healthy range for the escapement of these two stocks.

The waters contained within the boundaries of the park and preserve have received limited attention concerning fisheries. WRST has hired a Fisheries Specialist and several supporting staff to meet the fishery management needs at WRST. Several projects have been initiated that will provide valuable baseline information for fisheries management. Water quality and zooplankton samples are collected several times annually in Tanada Lake (Veach, pers. comm., 2003). A fish weir was also constructed on Tanada Creek and monitored throughout the summer of 2002 (Figures 6).

Figure 6. Fish counting station on Tanada Creek.

Alaska Statute 16.05.870 requires a permit from the Alaska Department of Fish and Game Habitat Division before activities in, or use of, a stream, river or lake that has been specified as important for migration, spawning or rearing of anadromous fish. Activities include any construction or use that diverts, obstructs, pollutes or changes the natural flow or bed of a specified water body. *AS 16.05.840* requires a permit for the use of wheeled, tracked, excavating or long-dragging equipment in beds of these waterbodies. *AS 16.05.840* requires that durable and efficient structures for fish passage be provided for every obstruction across a stream frequented by fish (State of Alaska, 1984).

There are several management plans that allocate fishery resources among users, providing managers in and around WRST with guidelines to maintain a sustained yield of fish stocks. These plans include the following (National Park Service, 1999a):

> *50 CFR Part 100 Subsistence Management Regulations for Public Lands in Alaska, Subpart C and Subpart D* – Federal regulations governing subsistence harvest of fish throughout the park/preserve as well as the Copper River.

5 AAC 01.647 Copper River Subsistence Salmon Fisheries Management Plan – This plan ensures that adequate escapement of salmon in the Copper River system occurs and that subsistence uses are accommodated. This plan pertains only to those salmon that pass the ADF&G's sonar located at Miles Lake.

5AAC 24.360 Copper River District Salmon Management Plan – This plan directs the ADF&G to manage the Copper River District commercial salmon fishery to achieve a biological escapement goal of 300,000 sockeye salmon and 17,500 other salmon into the Copper River. This plan also allocates salmon to subsistence, personal use and sport fisheries.

5AAC 77.590 Copper River Personal Use Dip Net Salmon Fishery Management Plan – This plan addresses the Chitina dip net fishery and requires a personal use permit for participation.

5AAC 75.013 Cook Inlet and Copper River Basin Rainbow/Steelhead Trout Management Plan – This plan was adopted to provide future Boards, fisheries managers, and the sport fishing public with:

- Management policies and implementation directives for area rainbow and steelhead trout fisheries;
- A systematic approach to developing sport fishing regulations that includes a process for rational selection of water for special management; and
- Recommended research objectives.

Recreational angling opportunities within WRST are limited, primarily due to lack of access to many water bodies. There are numerous water bodies that could provide additional angling if access were developed. The state of Alaska encourages the NPS to support the State's recreational fishing program and assist by developing or upgrading access routes as identified by the State's sport fisheries objectives (State of Alaska, 1984). The NPS is also requested to cooperate with the State in the collection, interpretation, and dissemination of research data, statistical data, banding and tagging records, population data, census information, harvest tabulations and other use information for fish in WRST.

Anadromous fish streams throughout the state have been cataloged by the Alaska Department of Fish and Game. These catalogs are available and the NPS is encouraged to use them during their planning process. The Alaska Department of Fish and Game welcomes NPS participation in the annual updating of these catalogs (State of Alaska, 1984).

There are numerous and complex fishery issues and information needs that extend beyond the objectives of this report or a more comprehensive Water Resources Management Plan (WRMP). WRST should consider development of a park-specific Fisheries Management Plan that further addresses the complex fisheries issues and management approaches that fit into the regional context of fisheries management.

Non-Federal Lands

WRST arguably has the most complex land status of any NPS unit, with over 700,000 acres of private, state, native, and university lands inside the boundaries. Access to non-federal lands over park lands via off-road vehicles (ORVs) and aircraft, plus land uses such as commercial, residential development, logging, and mining add to the management challenge (National Park Service, 2001b). Several small communities are located on these lands within the park, as well as numerous hunting and fishing lodges and private cabins. WRST is concerned with waste management, which can threaten aquatic resources if best management practices are not employed. The surface disturbance caused by development can also contribute to sedimentation problems and wetland impacts, while the storage of fuels on inholdings increases the risk of accidental spills into the environment.

Access is guaranteed to nonfederal land, subsurface rights, and valid mining claims, but any such access is subject to reasonable regulation to protect the values of the public lands that are crossed (ANLICA, sections 1110 and 1111). Existing regulations (43 CFR 36.10) govern access to inholdings. The use of ORVs for access to inholdings may be allowed under 43 CFR 36.10 by the Superintendent on a case-by-case basis on designated routes. The use of ORVs for access to inholdings will only be allowed upon a finding that other traditional methods of access will not provide adequate and feasible access (National Park Service, 1986). The use of ORVs by local rural residents for subsistence purposes may be permitted on designated routes, where the use is customary and traditional under a permit system implemented by the Superintendent. The Superintendent will designate routes in accordance with 36 CFR 13.46 (National Park Service, 1986). Management prescriptions that minimize and mitigate ORV impacts to designated trails in WRST are needed (*Project Statement: WRST N504.01*). There is also the need to determine the customary and traditional means and use of access points and routes as they relate to the temporal and spatial use of subsistence resources (*Project Statement: WRST S100.01*).

The McCarthy Road (59 miles) and Nabesna Road (42 miles) are the only two public roads that traverse WRST. Additionally, these are the only two roads that provide reasonable access for park visitors and residents within the park and preserve. Both roads are located within right-of-ways that were conveyed to the State of Alaska as a result of achieving Statehood. In the case of McCarthy Road, material sites rights-of-way were also obtained by the State prior to establishment of WRST. Material sites right-of-way were not obtained by the state for Nabesna Road (National Park Service, 1998a). Both WRST and the State desire to have these roads improved and adequately maintained. Unfortunately, resource management information (i.e., wetlands mapping, stream morphological data, etc.) along these road corridors is lacking. Roadside disturbance and damage from lack of vegetation and subsequent soil erosion exists. Gravel pits along these roads also impact the local hydrology by diverting surface and subsurface flows.

An intergovernmental work group has been established to manage both McCarthy and Nabesna roads. WRST will work cooperatively with the State of Alaska Department of Transportation to develop a McCarthy and Nabesna Road Plan. The reconstruction project will require significantly more sand, rock and gravel than needed in the past (Ziegenbein, 1998).

Nabesna Road

The Alaska Department of Transportation and Public Facilities (ADOT&PF) has a 200-foot right-of-way for the total length of the Nabesna Road. Materials needed to maintain the road have been obtained along the roadway corridor, which has left unvegetated scars. Of the twelve gravel pits adjacent to Nabesna Road, 25 percent exhibit ponding and 58 percent experience soil erosion (National Park Service, 1998a). According to Cook (1988) the most significant finding associated with the Nabesna Road gravel pits is the lack of organic topsoil at 11 of the 12 sites. Studies on revegetation of subarctic disturbed sites indicate the most important factor in native revegetation is the preservation or replacement of the upper organic layers of soil (Johnson, 1976; Shaver et al., 1983; and Johnson, 1987). Revegetation of sites without topsoil is extremely slow. For example, gravel pits in northwestern Canada had a mean of 30% vegetated substrate after 33 to 37 years (Kershaw and Kershaw, 1987).

Nabesna Road fords several aggrading streams. These stream fords must be continuously maintained to keep the road passable (Figure 7). Adequate conveyance of stream flow through the roadway is currently inadequate. In driving along Nabesna Road, several culverts appeared to be undersized and grading of the road tended to channelize overbank flows, intercepting and routing it down the roads gradient instead of flowing into the drainage on the other side of the roadbed. During the spring thaw or after a heavy rain, Skookum Creek near Devils Mountain Lodge, is temporarily impassable and constitutes the end of the road. Very little hydrological data exists for these streams for road design purposes. Little Jack Creek, located at mile 25.8 on Nabesna Road, is a partial-record station monitored by the U.S. Geological Survey (Station #: 15470300) since 1975. With a drainage area of 6.73 mi^2, a maximum period-of-record discharge of 254 cfs was recorded at this station in 2001 (Rosenkrans, pers. comm., 2003).

The NPS and ADOT&PF are given the responsibility by laws, regulations and policies for the design and construction of restoration and enhancement projects for Nabesna Road. According to a 1993 Nabesna Road Scoping Document, the agencies' prime objective is cooperation in achieving the following goals:

- Provide a safe roadway that can be efficiently maintained.
- Enhance the aesthetic qualities along the corridor.
- Rehabilitate previously disturbed areas.
- Enhance visitor/tourist use.
- Assure access compatible with NPS management plans.
- Maintain the scenic and primitive character of the corridor and surrounding areas.

Figure 7. Road Maintenance along Nabesna Road.

The Batzulnetas Trail connects Nabesna Road with Tanada Creek, Copper River, and the site of the Batzulnetas. At the end of the trail are three Native Allotments. A significant ethnographic, historic and archeological site, including a number of graves is located at the end of the trail. Federal land managed by the NPS surrounds the allotments and trail. Currently, there is the need to improve the trail so the elders can access Batzulnetas site, yet not encourage visitors to come down the trail.

An access road off Nabesna Road to a private inholding at Jack Lake currently travels in the narrow floodplain of Jack Creek, where streambank erosion and road maintenance are in constant competition. Jack Creek is a non-glacial stream that is biologically productive (National Park Service, 1990a). The NPS authorized maintenance of this roadbed, including grading, ditching, and filling in holes under Special Use Permit (WRST 9500-H028), which expires March 2004. Alternative routes for the road, outside the influence of Jack Creek, are under consideration by WRST staff. Realignment and construction of a new roadbed outside of the floodplain is a more desirable alternative.

McCarthy Road

The McCarthy Road follows the basic alignment used by the Copper and Northwestern Railroad. In 1971, the State completed the bridge across the Copper River. Since the opening of the road, the Alaska Department of Transportation has gradually upgraded the road bed through maintenance operations, but funds for such operations are always inadequate for major improvements such as culverts and the driving surface (Alaska Department of Transportation & Public Facilities, 1989). In 1995, an Interagency Planning Team (IPT) was formed to conduct a study of the road corridor between Chitina and McCarthy. The IPT was composed of representatives from the NPS, ADOT&PF, Alaska Department of Natural Resources, and Alaska Division of Parks. Field investigations along the road corridor to identify existing natural, scenic, historic, cultural, and recreational resources were conducted during the summers of 1995 and 1996. In the fall of 1996, alternative scenic corridor plans and trail scenarios were prepared. Alternatives ranged from "no build" to roadside development (Alaska Department of Transportation & Public Facilities, 1997).

The ADOT&PF has a 100-foot right-of-way for the total length of the McCarthy Road. To keep McCarthy Road passable, the ADOT has historically mined material for road repair from within this right-of-way. It has recently been determined that the holder of the right-of-way, in this case ADOT, is not entitled to the mineral rights of the right-of-way for extraction (i.e., gravel mining) (Ziegenbein pers. comm., 2003). The continued maintenance of the McCarthy Road by the ADOT is mutually beneficial to the NPS, the State, and local communities and residents. Unfortunately, the mining of material for road repair from within the right-of-way has created the following negative effects (Ziegenbein, 1998):

- Inferior materials for road repair and surfacing.
- Visual impacts adjacent to the road.
- Disruption of wetlands and floodplains.
- Disruption of historic and cultural resources.

McCarthy

The town of McCarthy is located on an alluvial terrace near the confluence of McCarthy Creek and the Kennicott River in the center of WRST (Jones and Rosenkrans, 1993). The small town emerged in 1899 when copper ore was first discovered in the area. In 1939, when mining ceased in the area, the population of McCarthy dropped from approximately 3000 to 100 (U.S. Department of Agriculture, 1988). Several of the old buildings have been renovated and are inhabited, mainly during the summer. The town receives a lot of seasonal use during the summer months.

McCarthy Creek forms the south border of McCarthy, and discharges to the Kennicott River approximately 0.5 miles west of the town (USGS stream station: 15210025). The drainage area of the creek at this location is 79 mi^2 (Meyer et al., 2001). The creek is a high-energy stream, originating approximately 18 miles north of McCarthy at McCarthy Glacier (U.S. Department of Agriculture, 1988).

McCarthy Creek threatens some of the private properties at McCarthy during high flows. Bank erosion and channel aggradation from the creek pose a serious threat to buildings and other property along the south side of McCarthy. McCarthy Creek has a history of flooding, eroding the banks, and depositing sediments several feet thick in and around this development. After a damaging flood in 1980, residents took measures to protect property from flooding, installing retaining walls and gabions along the developed floodplain of McCarthy Creek. The current creek impacts to the south portion of

McCarthy include severe bank erosion on the upstream portion and channel aggradation along the downstream portion. According to the U.S. Department of Agriculture (1988), the upstream erosion is a result of a reduction in stream channel slope, where the creek looses its vertical cutting power and finds it easier to erode finer stream bank material. Downstream, the reduced channel slope is causing decreased flow velocities and subsequent deposition of sediments.

In a 1988 study by the U.S. Department of Agriculture - Soil Conservation Service, the flooding problems were evaluated at McCarthy. In looking at photos (circa 1920s) of the area, McCarthy Creek was a straight deep channel, much different from the curving, shallow channel of today. One theory from the study was that the creek was channelized when constructing the bridge that spanned McCarthy Creek, which was washed away in the 1980 flood. Since the 1920's, many tons of material have been deposited in the creek bed, greatly reducing channel capacity and causing periodic shifting or at some locations, a division of flow channels (U.S. Department of Agriculture, 1988). The 1988 study introduced several structural measures for planning considerations that address erosion and aggradation/flooding: *Erosion protection*: 1) trench with stacked gabions 2) flatten bank with riprap or gabion basket armor. *Aggradation/flooding protection*: 1) stacked gabion dike and 2) earth dike with gabion armor. During the author's visit of McCarthy Creek, several rock vanes built in 2000 were in place, tied into the stream bank, deflecting the stream's energy away from the bank (Figure 8). Other NPS units (i.e., Buffalo National River) have had great success in protecting sensitive riparian areas using this design.

Figure 8. Rock vanes (below yellow lines) along north bank of McCarthy Creek at McCarthy.

A study by Hecht and LaChapelle (1994) on the water supply at McCarthy has led to identifying more data needs for the area. The key unknown for most management purposes is how far upstream Clear Creek, the primary water supply, receives recharge from McCarthy Creek. Further information is needed regarding potential sources of recharge north and south of the main airstrip, and in the watershed of Woodlot Creek. In the event that Clear Creek proves to be irrecoverably contaminated, identification of a new water supply will be needed. Measures to protect wellhead areas for the alternate supply sources are warranted before they are committed to uses, which may have adverse water quality effects. Potential alternate water supplies identified by Hecht and LaChapelle (1994) for the McCarthy area include: 1) underflow of McCarthy Creek, 2) development of springs emanating from bluffs at the west end of the old airstrip, and 3) development of the marl spring located 0.6 miles upstream of town along the south bank of McCarthy Creek.

Chisana

In 1996, the hydraulic engineer at Denali National Park and Preserve and the WRST geologist assessed the channel and floodplain conditions of Chathenda Creek (*Project Statement WRST N306.01*). This was in response to the owner of a private inholding along Chathenda Creek requesting to construct bank protection dikes on the river (NPS property) to protect his property. Chathenda Creek passes through the town of Chisana. It is a glacier feed drainage, where heavy rainfall and snowmelt produce the highest stream flows. The town is situated in the lower reaches of the creek upon its alluvial fan. A portion of the alluvial fan is subject to stream channel migration, aggradation, and scour as the stream attempts to adjust the high sediment loads. Prior to the establishment of WRST, area residents diverted the channel, excavated channels and constructed gravel berms in an attempt to “control” the creek. Portions of the historic mining district and private property are threatened by channel migration and associated scour and deposition (National Park Service, 1998a).

Field work was conducted to assess the current channel conditions, and possible impacts from the proposed protection project. The field inspection revealed an extremely active drainage course, with high sediment loads continually being deposited. Additionally, the drainage course is littered heavily with tree trunks and other vegetation that has been washed downstream. Several large remnants of old spruce forest floodplain are scattered out in the drainage course, indicating a much narrower drainage course at some recent time. Though braided rivers are by nature unstable, the evidence on this system implies extreme instability, probably due to some historic disturbance. Two disturbances in the watershed that were the likely source of this instability were hydraulic mining and logging. Hydraulic mining was extremely disruptive, destroying upland and riparian vegetation, contributing to excessive sediment loads to the creek. The extensive logging in the area also weakened the structural stability of the floodplain along both sides of the stream channel. At the advice of the NPS-Water Resources Division in 1994, NPS staff surveyed the floodplain margin and channel cross-section to better understand the hydraulic conditions of the creek, including discharge measurements, pebble count and slope determinations. In order to estimate various hydraulic parameters over a range of flood flows, a channel cross-section model (XSPRO) was used. The results from this effort confirmed the field observations. Material is moving at flows less than bankfull. This is due to the steep slope and excess sediment supply. The stream channel near the old town site is currently undergoing aggradation, due to excessive material being transported downstream from the steeper gradient reaches. The riparian zones along the stream banks are currently being impacted by gravel deposition and channel erosion. These forces are definitely threatening private property, as well as some of the historic structures located in the old town site. Based upon this assessment, the NPS concluded that bank protection proposed by the private landowner (Ray McNutt) would have no significant adverse impacts to this stream system, thus stream bank stabilization was authorized (National Park Service, 1996a).

<u>Copper-Tanada Lake</u>

The five-acre property and structures of a private landowner (Richard Frederick) on Copper - Tanada Lake are subject to inundation, bank erosion, aggradation, and channel migration (Inlet Creek) during flood events. The Copper-Tanada Lakes alluvial fan is a dynamic system subject to flood induced erosion, sediment deposition, and extreme changes in channel location creating a large hazard zone. The large alluvial fan (1.3 mi^2) consists of coarse volcanic debris that has been deposited between Copper and Tanada lakes. Inlet Creek cuts through the fan westward into Cooper Lake, draining 20.8 mi^2 of upland basin with four glaciers. Historically the active stream and flood channels periodically flowed northward and eastward into Tanada Lake. The Army Corps of Engineers authorized the property owner to conduct activities including bank stabilization under their nationwide permit in 1978. After constructing an airstrip and the initial bank stabilization, floodwaters repeatedly threatened the property. A gabion (3 feet x 3 feet x 350 feet) was constructed in the 1990's to divert water. Aggradation upstream of the gabion prevents it from functioning properly. The owner has repeatedly modified the channel and floodplain since construction of the airstrip. Attempts by the property owner to protect his airstrip and property by berming and channelization have had limited success, with most of the physical evidence of these previous activities reclaimed, revegetated or destroyed by natural processes. In 1996, the private landowner requested a special use permit to channelize and divert the active stream channel within the lower reaches of the "Copper-Tanada Lakes" alluvial fan. WRST's preferred alternative of the permit included a combination of: 1) allowing the requested design to divert stream flow from the active channel (north branch) into an intermittent low flow channel (south branch) within Inlet Creek for a five-year period, while following several NPS stipulations and, 2) consideration of long-term options that include, but not limited to, structure relocation, acquisition, and land exchange (National Park Service, 1996b).

Navigable Waters

In 1980, the State of Alaska established a navigability program to respond to federal land conveyances and land management activities under the Alaska Statehood Act, the Alaska Native Claims Settlement Act, and ANILCA. The basic purpose of the state's program is to protect the public rights associated with navigable waters, including the state's title to submerged lands. Because state, federal and native land parcels blanket the state, navigability questions have arisen for Alaskan rivers, lakes and streams. While the navigability of many of these waterbodies for conveyance purposes has already been established, navigability for title has not been determined for most waterbodies.

A major goal of the state's navigability program is to identify the proper criteria for determining title navigability in Alaska and to gather sufficient information about the uses and physical characteristics of individual waterbodies so that accurate navigability determinations can be made. The greatest hurdle to overcome in identifying and managing navigable waters in Alaska has been the differences of opinion between the state and federal government regarding the criteria for determining title navigability. It is the position of the federal government that waters and submerged lands within the boundaries of NPS units created prior to Alaska statehood are federally owned (Gilbert, pers. comm., 1999). The criteria for navigability takes into account geography, economy, historical use, customary modes of water-based transportation, and the particular physical characteristics of the waterbody. Final court decisions in Alaska are still needed to provide legal guidance for accurate navigability determination (Alaska Department of Natural Resources, 2003).

The Chitina River from the Copper River to the east line of Township 5 South, Range 7 East and the Copper River, where located within the boundary, up to the confluence with the Slana River, has been determined navigable by the Bureau of Land Management (National Park Service, 1986).

Hydrologic Hazards

Hazards associated with hydrological processes are scattered throughout WRST. Outburst floods (jökulhlaup), landslides, snow avalanches, and advancing glacial systems are hazards in the park and preserve that threaten property, transportation links, and human life. Since these are natural processes, the NPS objective is to develop a better understanding of these hazards in order to protect life and property when they occur.

Executive Order 11988 "Floodplain Management" requires the NPS to manage the use and occupancy of floodplains in a manner that minimizes flood risk to humans and structures and minimizes impacts to floodplains resources and processes. The policy and procedures used by the NPS to implement EO 11988 is found in Director's Orders 77-2. In brief, it is NPS policy to avoid the use of the regulatory floodplain whenever there is a practicable non-floodplain alternative and to restore, preserve, and protect floodplain values. The regulatory floodplain is defined in DO as the 100-year, 500-year, or maximum floodplains depending on the situation. When it is necessary to use the regulatory floodplain or cause impacts to the regulatory floodplain, a statement of findings is prepared describing: 1) why the floodplain must be used or impacted, 2) the level of risk to humans, structures, and/or the environment that is being taken in association with the action, and 3) how the risk will be mitigated. Only one floodplain has been identified along the Kennicott River. Jones and Glass (1993) defined channel and flood characteristics at selected sites in the Chitina River drainage (Chititu Creek, May Creek, Kennicott River, McCarthy Creek, Nikolai Creek and Strelna Creek). There are six major rivers and numerous smaller tributaries located in the park and where park infrastructure is present or planned or an NPS-supported action occurs, floodplain delineations may be necessary in the future to ensure compliance with the floodplain EO and DO (Smillie, pers. comm., 2003).

The Kennicott River basin originates on the south side of the Wrangell Mountains and terminates at the confluence with the Nizina River (Figure 9). The basin upstream from McCarthy Creek is 352 mi^2 (Rickman and Rosenkrans, 1997). The basin is prone to several natural hazards: flooding from rain, snow and ice melt, and outbursts from glacial dammed lakes; channel migration; erosion and deposition in outwash plains and alluvial fans; landslides; and snow avalanches. Usually one or more large floods occur each year when glacier-dammed lakes suddenly release impounded waters. Six such lakes have been identified in the Kennicott River basin; Hidden Creek, Erie, Donoho, Gates, Jumbo and Bonanza lakes (Figure 9). Some of the physical characteristics of these lakes are presented in Table 3.

The highest discharge in the Kennicott River occurs during outburst events from Hidden Creek Lake. Historically, Hidden Creek Lake has drained annually during the late summer or early fall, with outbursts occurring between July and mid-August since 1988. Each jökulhlaup's magnitude changes through time as the glacier it issues from thickens or thins. According to Friend (1984), the glacial-dammed lakes release when the waters' height is approximately nine-tenths of the ice thickness. Criteria for impending outbursts for Hidden Lake include lake stage near or above 3000 to 3020 feet, stationary or declining lake stage, evidence of recent calving of large ice blocks from the ice margin, slush ice and small icebergs stranded on the lakeshore, and fresh fractures in the ice-margin region (Rickman and Rosenkrans, 1997). Destruction of the railroad and vehicle bridges that once spanned the Kennicott River is evidence of the powerful and dynamic nature of the river in flood stage (National Park Service, 1998a). McCarthy is situated one-half mile from the present terminus of the Kennicott Glacier and lies at the confluence of McCarthy Creek and Kennicott River. This town is the main business district of the McCarthy/Kennecott areas and is easily accessible via an unimproved gravel road (McCarthy Road).

The NPS Water Resources Division visited the Kennicott River area near McCarthy to collect data for an outburst flood analysis and to consult with park staff regarding geomorphic stability of glacial deposits (Martin, 1995). A glacial deposit presenting a possible landslide hazard was examined on the right bank of the Kennicott River near McCarthy. The river terrace below the deposit is regularly used for camping and located within a debris flow zone. Evidence of repeated debris flow activity was prevalent at the base of the feature and considered a risk to the camp area. The configuration of the Kennicott River channel was assessed and determined to be unstable in the vicinity of McCarthy. Three channel cross-sections on each of the two branches of the Kennicott River were monumented and surveyed in 1995. It was recommended to re-survey these same cross-sections on a scheduled frequency to calculate changes in channel/floodplain parameters and evaluate the resulting change in flood hazard for the area.

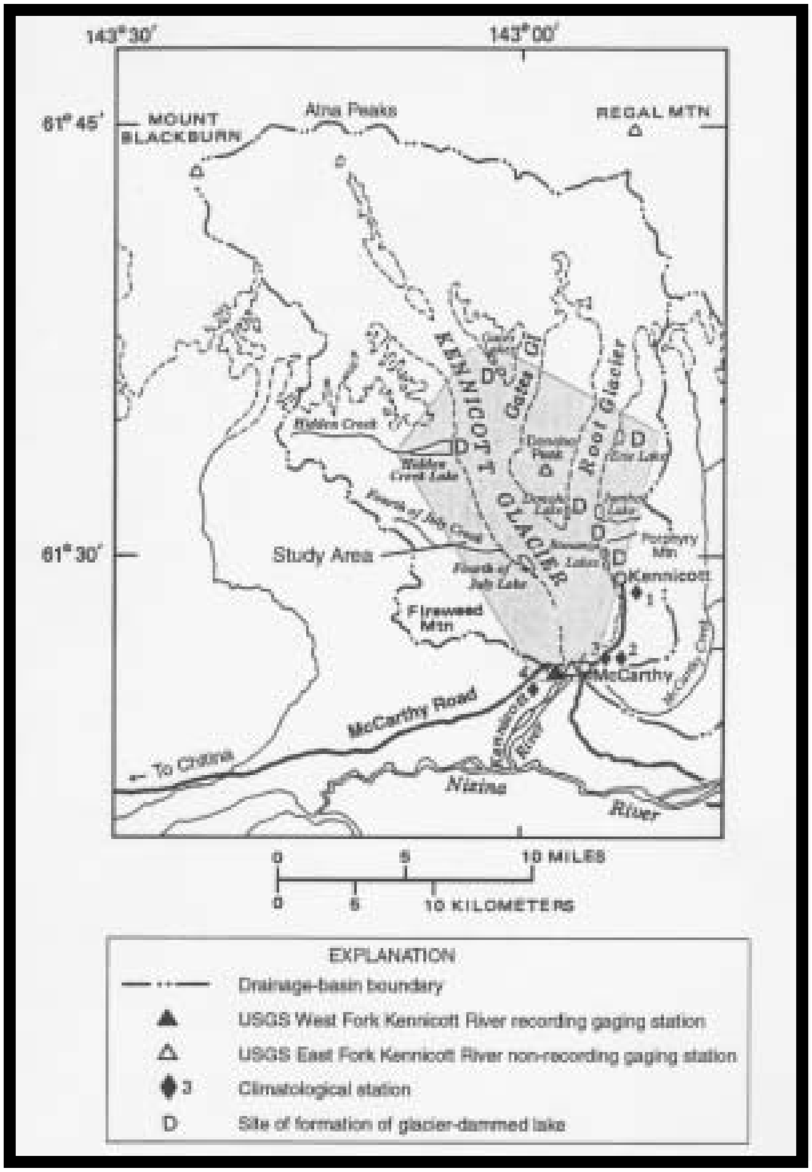

Figure 9. Location of glacier-dammed lakes in the Kennicott River Basin (Rickman and Rosenkrans, 1997).

Table 3. Selected physical characteristics of glacial-dammed lakes in the Kennicott Basin (Rickman and Rosenkrans, 1997).

Lake Name	**Distance up-glacier from McCarthy (miles)**	**Surface elevation[1] (feet)** **USGS 1908 datum**	**Estimated depth[1] (feet)**	**Approximate surface area[1] (mi^2)**
Hidden Creek	10	3,000	350	0.5-0.75
Erie	9	3,000	>100	0.12
Donoho	6	2,500	>100	0.03
Gates	12	3,400	unknown	0.012-0.015
Jumbo	5	2,100	50-75	0.02
Bonanza	3.8	2,000	75-100	0.008-0.013

[1] At maximum observed lake stage.

WRST has prepared a proposal (*Project Statement WRST N 305.00*) to determine the magnitude, frequency, and response time for outbursts floods from Hidden Creek Lake, other glacial dammed lakes along Kennicott Glacier, and rain induced floods. Surveying and monitoring active stream channels in the Kennicott and McCarthy drainages around McCarthy is also recommended. During the 1995 visit by the NPS Water Resources Division, the lake basin and stage data were collected in Hidden Creek Lake to further the analysis of the annual outburst flood. Survey control established by the U.S. Geological Survey and NPS in 1994 was reoccupied and the Hidden Creek Lake base topographic survey was repeated (Martin, 1995). These data were used in conjunction with survey data collected in the summer of 1994 to substantiate a previously prepared bathometric map. From these data and the existing map, a stage-volume rating curve was estimated for the lake basin. Periodic observations of lake stage in the future will aid in prediction of the relative magnitude of the outburst flood. The information collected by NPS Water Resources Division was used in producing a USGS Report (Rickman and Rosenkrans, 1997) that describes the hydrologic conditions and hazards in the Kennicott River Basin. From this report, a potential flood magnitude of 48,300 cfs was estimated by combining known maximum discharges from Hidden Creek and Erie lake outburst floods with a large regional flood. The flood hazard zone was delineated using channel geometry surveyed in October 1994. Additional research was conducted in 1999-2000 on the hydrology and outburst event by the University of Washington and University of California, Santa Cruz (Rosenkrans, pers. comm., 2003).

In July 1997, the glacier fed creek entering Tebay Creek at Tebay Lake outlet suddenly went into flood stage. Floodwaters were observed transporting and depositing mature spruce trees and boulders (b-axis to 50-65 cm) within the alluvial fan and its confluence with Tebay Creek. A second flood event occurred later that summer. WRST and U.S. Geological Survey staff estimated that debris deposited in the outlet reach resulted in an estimated 10 feet of aggradation during the past 30 years. Most of which appeared to have occurred during 1997. Aggradation by the two major floods caused the lake level to rise approximately seven feet, flooding the adjacent shoreline areas. Although the lake level has dropped slightly since the 1997 event, it is not expected to return to its pre-1997 stage for some time due to the inability of Tebay Creek to reestablish its old channel configuration.

Documentation of glacial sediment production rates is critical to understanding the roles of glaciers in landscape evolution and in global geochemical cycles. Proglacial lakes like Iceberg Lake and Hidden Creek Lake offer an excellent opportunity to investigate sediment production in a non-tidewater glacier environment, but access to their sedimentary record is rare. Although glacier-dammed, there is no historical record of Iceberg Lake draining prior to 1999. The lake's apparent stability has been punctuated by prehistoric lake-lowering events, corroborated by 1) a series of five well-developed shorelines, 2) a correlated series of sandy deltas, and 3) strongly-varved lacustrine sediments containing several high sedimentation events (Loso et al., 2002). During the author’s field visit in 2002, a jökulhlaup occurred from Iceburg Lake, resulting in extensive flooding along the Tana River (Figure 10).

Figure 10. Iceberg Lake immediately after the August 2002 outburst (jökulhlaup).

The Hubbard Glacier, located along WRST’s coast near Yakutat continues a slow advance that has been observed since about 1895. During the summer of 2002, the glacier blocked the entrance to Russell Fjord from Disenchantment Bay, forming a 39-mile long lake. During the blockage, water continued to flow into the fjord, causing the water level to rise a half foot per day. The U.S. Forest Service convened a multidisciplinary team of specialists to implement monitoring strategies and reactivate monitoring sites in the impacted area. If the water were to get deep enough, Russell Fjord could drain southward into the Situk River drainage outside WRST’s boundary, increasing the average discharge by tenfold (Paul, 1988), altering a world-class fishery and inundating national forest and private lands. Fortunately, the ice dam broke before this happened in August 2002, releasing an estimated peak discharge of 1.8 million cfs. The U.S. Forest Service is taking the lead in the dissemination of information about this hydrologic hazard; the U.S. Geological Survey is providing research and technical expertise; and an interagency team of Forest Service, National Park Service, and U.S. Geological Survey representatives will provide ongoing monitoring (National Park Service, 2002b). The previous closure of Russell Fjord's connection to Disenchantment Bay water occurred in 1986. The U.S. Geological Survey expects the closure to occur again within the next year or two, due to the recent influences from the terminal moraine (Molnia, pers. comm., 2003). The National Park Service will continue to participate as a component of the interagency team that includes the U.S. Forest Service and U.S. Geological Survey (National Park Service, 2002b).

Landslides are common in WRST, with scars from recent and historic slides dotting the landscape (Figure 11). The combination of steep gradients and unconsolidated soils produces areas prone to landslides under the right conditions. In the upper reach of McCarthy Creek where valley walls are steep, landslides have deposited large quantities of materials ranging in size from clay to boulders. Large concentrations of landslides within the headwaters of Nikolai Creek tributary contribute to high sediment loads to this stream. In 2003, a large landslide occurred along the West Fork of the Nizina River that impacted the landscape extensively (Rosenkrans, pers. comm., 2003). Intense, prolonged rainfall, rapid snowmelt, saturated soils, thaw of frozen soils, and earthquakes are major factors contributing to failures of unconsolidated deposits on steep slopes. A slope failure may be gradual or rapid. A failure may start as a sliding failure (debris slide). As it moves downslope, it may accelerate to become a debris avalanche, or with increased liquefaction, it may develop into a debris flow. A debris flow may also be produced when a large volume of soil and rock reaches a stream channel and materials become mixed with water in the stream (Jones and Glass, 1993). If landslides are large relative to the streamflow, they can block the flow and cause impoundment and flooding above the dam site. If the dam fails catastrophically, large volumes of water and sediment are suddenly released, threatening park staff and visitors. It is important for WRST to build from the assessments conducted around McCarthy by Jones and Glass (1993) and identify other areas in the park and preserve susceptible to landslides and debris-flow hazards. Methods for predicting, analyzing, and controlling soil mass movement are described by Schuster and Krizek (1978) and Sidle et. al. (1985).

Coastal Management

Approximately 125 miles of the southeastern boundary of WRST is delineated by the mean high tide line of the North Gulf Coast of Alaska. This coastal zone provides important habitat for marine mammals, waterfowl, shorebirds, commercial and sports fisheries, and subsistence activities. This zone also serves as an important flyway for migratory birds.

The North Gulf Coast experiences some of the harshest marine weather conditions in the world. As a result, the possibility of accidents that impact WRST’s coastal environment is very real. Boating accidents in the area are common. In 1989, the tanker vessel *Exxon Valdez* grounded in Prince William Sound, rupturing cargo tanks and spilling

Figure 11. Landslide into the Chitina River looking downslope.

approximately 11 million gallons of crude oil into the sea. This accident resulted in the most extensive single human-caused disaster to ever strike national parks (National Park Service, 1990b). Coastal winds and currents transported the oil slick southwest along the north shore of the Gulf of Alaska. Fortunately, WRST's coast was just outside of the areas impacted by this large spill, but natural resource threats such as this will always exist for coastal parks in the region. Recent shipping losses along WRST's coast have included a luxury cruise ship, several seagoing barges, and numerous fishing vessels (National Park Service, 1998a). An accident to an oil tanker or barge hauling hazardous substances could be disastrous for WRST's coastal environment. The strong currents and a high tidal range in the Gulf of Alaska can transport spills great distances from their source.

Water discharged from cruise ships into the ocean has higher nutrient concentrations than the ocean. The discharge water is composed of different types of wastewater from various locations within the ship and, depending on the ship, includes gray water (i.e. that from showers and sinks, laundry facilities and the galley) as well as treated sewage. The discharge of raw sewage or untreated black water is prohibited in Alaska. Total nitrogen and phosphorus (as phosphate) in these different waters have concentrations ranging over several orders of magnitude (Smith, 2000) based on summer 2000 data. High nutrient concentrations (nitrogen, phosphorous) in wastewater discharge can, under the right conditions, promote phytoplankton blooms in receiving waters, altering the immediate marine environment (Atkinson et al., 2003).

The Alaska Department of Natural Resources manages these tidally-influenced environments. The U.S. Coast Guard and Alaska Department of Environmental Conservation share responsibility for oil spill prevention, containment, and clean-up. A liaison between WRST and these agencies does not exist. Currently, WRST does not have sufficient baseline information on the conditions of their coastal environments.

This information is critical toward the efficiency and effectiveness of any spill abatement efforts (*Project Statement: WRST N405.00*).

Mining

There are more than 400 abandoned mineral and exploration sites in WRST. Some sites pose serious pollution threats to park water resources. Throughout 1985 and 1986, WRST conducted detailed inventories of hazardous wastes at 19 sites. From these inventories, 167,000 pounds of solid wastes (mostly stockpiled drilling muds), 133 containers of ignitable and non-ignitable hazardous liquids, and 310 pounds of unstable dynamite were found. Many additional sites have not been inventoried (National Park Service, 1998a). Until 1990, heavy metals leached into surface and ground water near the park's Malaspina Glacier from decomposed bags containing 83 tons of abandoned drilling muds. Pits containing drilling muds may be leaching pollution in the same area. In the northern part of the park, tailings from a cyanide vat leaching operation at the abandoned Nabesna mine are leaching heavy metals into surface waters. British Petroleum has since mitigated the site (Rosenkrans, pers. comm., 2003).

Past placer mining and other mining water diversions have severely disrupted stream channels, damaging or destroying fish populations and their habitat. Excavation activities and placer mining threaten park waters with excessive sediments. Lloyd (1987) and Lloyd et al., (1987) found turbidity was negatively correlated with primary production and fish production. WRST currently has 27 unpatented mining claims that consist of 491 acres of non-federal lands. There are also, 299 patented mining claims on 5875 acres of non-federal lands.

Direct drainage from mining operations is now regulated as a "point source" discharge under the permit system established by the Federal Water Pollution Control Act. The effectiveness of regulation under this permit system, however, is handicapped by lack of funds and personnel. There are also difficult factual and legal disputes about whether storm runoff and other natural drainage from mining areas should be regulated under the much less rigorous state programs for "non-point sources". Alaska's control strategy for non-point source pollution, though approved by EPA in 1990, fails to clearly identify and require "best management practices" for mining operations, and fails to address non-point sources of pollution generated by road building and other transportation activities related to mining.

Federal law allows for potential development of existing mining claims that had been staked in WRST prior to its establishment. Under regulations authorized by the Mining in the Parks Act of 1976, miners must obtain NPS approval of a "Plan of Operations" based on completion of an environmental analysis, before initiating mining activities. The NPS can require mitigation measures, and a bond is required to guarantee reclamation. If mining activity will cause "significant" adverse impacts, it can not be approved. The NPS from 1979-1985 granted "temporary" approvals of 30 to 50 mining plans annually in eight Alaska NPS units without completing the required environmental analysis or requiring any bonds. The environmental consequences were significant. NPS reports showed wastewater discharges grossly exceeded water quality standards at all operations tested. In 1985, the federal district court of Alaska declared the temporary approvals invalid, enjoined any further approval of mining plans without environmental analysis, and ordered preparation of an environmental impact statement (EIS) to assess mining impacts on three Alaska parks, including WRST. Completed in 1990, these EISs basically demonstrated that mining, if developed to any significant scale, was incompatible with the protection of park values. The final EISs recommended that Congress appropriate money to buy out mining claims in Alaska's national parks, including WRST, and pass legislation limiting future patents for mining claims in Alaska to mineable minerals rather than granting the whole surface and subsurface estate.

The NPS minerals management regulations for mining and mining claims under 36 CFR 9A govern all activities associated with the exercise of valid existing mineral rights on claims within any unit of the national park system. The scope of these regulations extends to all patented and valid unpatented mining claims established under the U.S. mining laws. The intent of the regulations is threefold (National Park Service, 1986):

- To ensure that mining activities occur in a manner consistent with the purposes of the national park system and its collective park units
- To prevent or minimize damage to park resource values
- To ensure that the park units and associated pristine values are preserved for the benefit of present and future generations.

All mining operations are to be conducted in accordance with an approved plan of operations as required by 36 CFR 9.9.

In a cooperative effort between the National Park Service and U.S. Geological Survey, environmental geochemical investigations were conducted between 1994 and 1997 at several areas in WRST. Sampling and analyses that included surface water and bedload sediment were carried out at five mineralized areas in the park/preserve and summarized below (Eppinger et al., 2000). It should be noted that the following discussions are limited to data collected during "low flow" conditions, excluding the Nabesna site, when concentration of pollutants would likely be minimal. Also, some of the physical habitat disturbances associated with the historic mining activities within these watersheds were previously described in the *Water Quality* section and should be referenced (National Park Service, 1990a). These disturbances have contributed to some of the changes in local stream morphology (i.e., changes in channel geometry) and water quality (i.e., increased turbidity and total dissolved solids).

<u>Kennecott</u>

Surface water samples from the Kennecott area have low metal concentrations that are generally comparable to world-wide average surface water concentrations (Eppinger et al., 1997). Kay (1990) also found water quality to be generally good in the creeks sampled (National, Bonanza, and Jumbo creeks). Only slight differences in cation and anion content are found between samples proximal and distal to the mines and mill. The low metal concentrations are due primarily to two geologic controls; 1) the widespread host carbonate rocks (Chitistone Limestone) that buffer waters in the area (pH 7.7 – 8.2), and 2) absence of unstable sulfide minerals. Although concentrations of potentially toxic elements such as arsenic, cadmium, copper, and mercury are found in mill and mine-waste piles, these metals are not mobilized because of the absence of acid-generating minerals in Kennecott-type deposits (Eppinger et al., 2000).

Gold Hill

The waters at the Gold Hill area are predominately calcium-bicarbonate, which is likely related to the common presence of calcite in the bedrock and alluvium. Weathered pyrite in the area probably accounts for the minor concentrations of sulfate in waters. The predominance of calcite over pyrite results in pH values above neutral. Minor magnesium, sodium, and potassium components in the surface waters may be related to the locally altered igneous rocks in the area. Eldorado Creek has the lowest pH and alkalinity values in waters from the area. Weathered pyrite-rich veins underlying the Big Eldorado drainage base could be the reason for stream waters having slightly lower pH (7.3) and alkalinity (16 mg/L as calcium carbonate), compared to the area's mean (91 mg/L). The low alkalinity suggests that Big Eldorado basin has less acid-neutralizing capability than elsewhere in the Gold Hill area. This characteristic, along with the known presence of pyritic rocks in the drainage, suggests that water quality should be monitored if the naturally reestablished equilibrium along Big Eldorado Creek is disrupted.

Surface waters in the Gold Hill area contain the highest mercury concentrations found in the Eppinger et al. (2000) study. Two of these comparatively high values, 0.054 µg/L and 0.036 µg/L mercury, are from sites along Bonanza Creek. Relatively high mercury values were also found in waters from upper Gold Run (0.035 µg/L) and upper Big Eldroado (0.033 µg/L). Although these are relatively high values for WRST, these mercury concentrations are two orders of magnitude below the Alaska Department of Environmental Conservation MCL of 2 µg/L. Water quality samples collected from the Gold Hill area during the dry summer of 1997 did not exceed any of the drinking water primary and secondary MCL's established for significant inorganic parameters. Whether these parameters exceed established limits during high-flow periods or during periods of placer mining activity, is unknown.

Orange Hill and Bond Creek

Waters in the Orange Hill area are calcium- and sulfate-dominated. Bicarbonate is a minor component of the water samples. The low pH values and high sulfate waters are a product of abundant pyrite and associated sulfate minerals and the minimal presence of carbonate minerals. Along the lower 1 km reach of Harq Creek, bedrock consists of pyritic, sulfate-rich, clay-altered bedrock. The pH along this reach ranges from 3.6 to 4.6. Outside of the clay-altered bedrock influence, pH is 7.7 where carbonate sedimentary rocks are present. During the 1996-1997 sampling periods, water quality was found to be significantly degraded in altered areas at Orange Hill and Bond Creek.

Many of the significant organic and inorganic parameters for drinking water listed by the Alaska Department of Environmental Conservation were found in concentrations well above established primary and secondary maximum contaminant level (MCLs). Water quality was generally good outside the areas of alteration. This area is a good example that demonstrates that mines and mills are not the sole source of acidic, metalliferous waters in the environment.

The waters of Orange Hill flow into the high-volume Nikonda Creek, which feeds into the Nabesna River. Similarly, degraded waters flow into Bond Creek, another high-volume creek above its juncture with the Nabesna River. Through mixing, neutralization of the acid and precipitation of the metals onto colloidal iron- and aluminum-oxides would be expected. This in combination with the rapid dilution by the high-volume river greatly reduce the toxicity of the waters as they move farther from the altered areas of Orange Hill and Bond Creek. It should be noted that these naturally occurring low pH waters create unique ecosystems that certain biota have adapted to and important to the larger naturally functioning ecosystem.

Bremner

The waters at Bremner have relatively low alkalinities where sulfate is the predominant anion over bicarbonate, pH is near neutral, and dissolved metal concentrations are low. The acids produced by weathered pyrite are neutralized by the bicarbonate (calcite vein), keeping pH values near neutral and metal mobility to a minimum. The low alkalinities and minor bicarbonate suggest that most of the available carbonate is being consumed by the neutralization process. If so, disturbing mine wastes or mill tailings would probably disrupt this naturally established equilibrium, possibly requiring active treatment (Eppinger et al., 2000). WRST staff was concerned about toxic levels of mercury in local waters since it was used historically to amalgamate gold at the Bremner mill. Mine wastes and ore samples from this area did not contain mercury exceeding the 0.02 mg/L detection limit. There was a 170 mg/L mercury concentration found in tailings at the Lucky Girl mill. Ten water samples collected from the Bremner area, including water flowing from the Lucky Girl mine adit and water from below the mill, contained mercury concentrations less than 0.025 µg/L (parts per billion), well below the Alaska Department of Environmental Conservation MCL of 2 µg/L. This suggests that mercury was not being mobilized in surface water during the dry 1996 summer sampling period, but mobilization during wet periods or spring breakup remains unknown for this site.

Nabesna

During the Eppinger et al. (2000) study, the Nabesna area was sampled during a range of climatic conditions that lasted three field seasons. Major ion composition of the waters sampled in the area varied considerably. In all water samples, calcium is the major cation. Major anion composition varies from sulfate- to bicarbonate-dominant. Values for pH range from 2.2 to 8.6, with a mean of 6.7. At Nabesna, waters flowing from the mill tailings piles, and leachates of the tailings material, are very acidic and metal-rich. For the major ions, the Alaska Department of Environmental Conservation primary MCL is exceeded in two spring run-off samples for fluoride. Secondary MCL's are exceeded for sulfate, aluminum, iron, manganese, and total dissolved solids. For trace ions, primary MCL's are exceeded for arsenic, cadmium, and lead. Secondary MCL's are exceeded for copper and zinc. Most samples exceeding the Alaska Departments Environmental Conservation MCL's were collected during spring breakup and extended summer rain events.

At Nabesna, periodic flooding by Cabin Creek flows onto the road and through some of the historic tailing deposits; thus contaminating the surface flows. Water samples collected from Cabin Creek contained high concentrations of manganese, zinc, iron, and hydrogen sulfide with a low pH. Aquatic macroinvertebrates are not present in the stream section directly downstream from the tailings; however, filamentous iron bacteria thrive (National Park Service, 1990a). As stated earlier, Cabin Creek is currently a 303(d)-listed impaired waterbody for manganese. The Alaska Department of Environmental Conservation staff has met with WRST to discuss options for a Cabin Creek recovery plan. WRST is currently working with the NPS Water Resources Division and Geologic Resources Division to look at options toward minimizing Cabin Creek's contact with tailings in the area.

The results from the Eppinger et al. (2000) study demonstrate that bedrock geology and mineral deposit type are critical aspects that must be considered in evaluating environmental geochemical effects of historic or active mine areas. Highly mineralized Cu-Mo porphyry belts in WRST can naturally produce elevated metal concentrations and low pH (acidic). In acidic systems, metals are more mobile. For example, naturally occurring lead found in stream sediments collected from the Nabesna area range from 10 to 1500 ppm (National Park Service, 1998a). Weather conditions and seasonal variation can strongly influence the geochemistry of waters, thus sampling only during similar weather conditions or the same season may mask some interpretations. Building from the Eppinger et al. (2000) study could include sampling during high-flow conditions (i.e., immediately after heavy rain events) to capture the "worst case" scenario for flushing contaminants through these fluvial systems.

Recreation Management

In 1985, WRST reported a total of 24,123 visitors, with 23,171 defined as recreational visits. In 2001, 28,656 visitors were recorded, with all but 13 recreational visits (National Park Service, 2003b). Recreational activities are an important contribution to the cash economy of the region. Sport hunting and fishing, requiring the services of guides, air charter services, accommodations and supplies bring cash benefits to many of the local residents (U.S. Department of the Interior, 1974). Year-round road access via the state highway system is available to the periphery of WRST.

As previously discussed, two roads penetrate the park/preserve: the 43-mile road from Slana to Nabesna in the north (Nabesna Road) and the 61-mile road from Chitina to the Kennicott River in the Chitina Valley (McCarthy Road). Both of these roads are located on rights-of-way managed by the state of Alaska; therefore, the state is responsible for maintenance and improvement of these roads. Because these roads provide major access into WRST, the NPS has an interest in the maintenance of these roads and any improvements that may be proposed (National Park Service, 1986.).

Use of snowmachines, motorboats, airplanes, and nonmotorized surface transportation methods for recreation purposes is permitted pursuant to existing regulations (36 CFR 1.6, 2.60 and 43 CFR 36.11 (d), (e), and (f)). Methods of nonmotorized surface transportation include domestic dogs, horses, and other pack or saddle animals. Except for subsistence use, the recreational use of all-terrain vehicles (ATVs) off established roads and parking areas is prohibited in WRST. The use of ATVs can result in damaged resources, contrary to existing laws, executive orders, regulations, and policy. In determining what designations and limitation regarding recreational use of motorized vehicles on primitive park roads are appropriate, the Superintendent will consider the potential for resource damage, user conflicts, trespass on private lands, and impacts on aesthetics, scenery, or other natural values (National Park Service, 1986).

There are approximately 600 miles of ATV trails. Of particular concern are the numerous areas where the trails traverse wetlands, permafrost soils, and steep slopes (National Park Service, 1998a). Past WRST studies indicate that ATV use has caused adverse impacts, including shifts in species composition, decreased frequency and cover of plant species, thermokarsting, erosion, and increased trail width (Cook, 1990). In 1984, a study of the environmental effects of ATV use was initiated in the northern part of WRST, near Tanada Lake. Experimental vehicle tests were designed to evaluate how vegetation, soils, and water were affected by four different types of ATVs (Honda ATC, 6-wheel Sidewinder, tracked sidewinder, and a Weasel). At the lowest traffic level of 10 passes, all four vehicles produced significant amounts of surface depression, herbaceous compression, and shrub breakage, with little or no change in the surface in terms of ponding or exposure of organic soil. At 50 passes, surface depressions, terrain surface changes, and shrub damage increased. The biggest difference in vehicle-type effects occurred at 150 passes with the Weasel and Sidewinder (wheels) producing deeper tracks with 70% - 90% exposed organic soil, standing water, and shrub damage, with the Honda and Sidewinder (tracks) producing less than 15% ponding and exposed organics and less than 50% shrub damage (Racine and Ahlstrand, 1985).

Research in other arctic areas has indicated that sites will continue to degrade if the organic mat has been destroyed, even if use ceases (Rickard and Brown (1974), Sparrow et al. (1978), Walker et al. (1987)). ATV use throughout the park and preserve has damaged lands with underlying permafrost, causing streams to be diverted from their natural course into subsided motor vehicle trail areas. Vehicle use appears to upset the freeze/thaw balance in the underlying permafrost layers by removing the insulating vegetative cover, promoting changes in hydrological conditions. ATV use along stream channels or banks increases sedimentation of rivers and streams, damaging important riparian vegetation and altering stream structure. WRST needs to evaluate the current ATV trails through the NEPA process and determine solutions to mitigate use on each trail. Comprehensive Environmental Assessments (EA) or Environmental Impact Statements (EIS) with many alternatives, including closing trails or restricting to subsistence use only, will be needed to assist park management (Sharp, pers. comm., 2003).

The WRST ATV Trail Impact Assessment and Mitigation Project began in 1995 with employees and volunteers studying various ATV trails as well as areas without trails. The project crew evaluated vegetation, soils, permafrost, subsidence (depth of trail rut), and many other factors. Then they began exploring ways to lessen the impact of ATVs. After careful consideration of the possibilities, it was decided to experiment with hardening the trails. In the summer of 1996, the working crew laid material, synthetic and natural, on sections of the different trail surfaces and ATV users were encouraged to drive on different plots. Testing ways of hardening the trails will give the park alternatives for preventing further impact. In 1997, WRST Resource Management Division continued to monitor these sections. A resulting report on both phases of this valuable study will soon be available.

There are unimproved airstrips in most backcountry regions of WRST. Fixed-wing aircraft may be landed and operated on lands and waters within the park/preserve. All federal lands within WRST are open to authorized aircraft uses. WRST provides limited maintenance on some of the 26 airstrips for the safety of both visitors and park employees (National Park Service, 2001b). Several of these airstrips contain fuel storage facilities that require scheduled maintenance and monitoring to minimize water quality threats to surface and ground waters in the immediate area (Figure 12). Many people currently land their fixed-wing aircraft on gravel bars, tundra ridges, and glaciers. In addition, many of the lakes are accessible by floatplane in the summer and ski plane in the winter (National Park Service, 1986).

Figure 12. NPS above-ground fuel tanks at McCarthy landing strip.

Increased human use at existing towns and visitor facilities in the area, as well as new facilities, could lead to substantial water pollution from human wastes which would necessitate expansion of existing or creation of new disposal facilities. Few sanitary and trash disposal facilities exist for the increasing number of visitors who camp on federal and non-federal land along the park's two main roads, creating pollution problems. Increased sewage and garbage disposal could increase nutrient loading into nutrient-poor ecosystems. This could substantially affect existing water quality and ecosystem equilibrium (U.S. Department of the Interior, 1974).

Copper, Ptarmigan and Tanada lakes have a relatively high recreational use because of their ATV and floatplane accessibility and presence of commercial lodges or spike camps at each lake. Potential human impacts were noted during general water quality surveys in 1991-1992. Several outhouses at Copper Lake and Tanada Lake were filled to a level above ground, and in one case the structure was built above a seasonal inlet rather than being dug into the ground. The extent of which human waste is affecting the lakes is not known, since bacteriological sampling was not performed during the survey (National Park Service, 1994a).

Several guides and commercial operators offer services within the park/preserve boundaries that rely on livestock, at present exclusively horses, for transportation of clients and gear. The public also brings livestock into WRST for recreational and subsistence activities. Grazing is a historical use of lands within WRST, and is allowed under special use permit. Little is known about the effects of grazing in Alaskan environments. Effects of livestock use on soils, plant communities, and water quality are unknown at WRST (National Park Service, 1998a). WRST should manage livestock use in a manner that does not result in unacceptable resource damage in the park/preserve (*Project Statement: WRST N506.00*).

WRST provides periodic maintenance for nine hiking trails that total approximately 100 miles (National Park Service, 2001b). Over time, many trail segments in a mountainous terrain deteriorate by natural processes and by wear from recreation traffic (Summer 1986, Tinsley and Fish 1985). The magnitude of trail deterioration is determined by characteristics of the trail, its environment, and the recreation use that the trail receives (Cole, 1987). On a trail in Great Smoky Mountains National Park, Whittaker (1978) found that horse use caused more pronounced increases in trail width, trail depth, and litter loss than hiker use. In a study of impact to existing recreational trails, Wilson and Seney (1994) measured the effect of user impacts, including hiker and horse traffic, on sediment yield following simulated rainfall. In the study, sediment yield following horse use was found to be significantly greater than hiker use. The increased sediment yields from trail use, under the right conditions, can enter a waterbody and degrade water quality through increased turbidity and total dissolved solids, and degrade aquatic habitat by covering the natural substrate through increased sediment deposition. In contrast, Summer (1980) was unable to detect differences in erosion rates between trails in Rocky Mountain National Park used by hikers and those used by horses, suggesting that trail characteristics and/or environment, contribute to the cumulative outcome on trail impacts.

Several issues exist at Kennecott, where the NPS is preserving the cultural mining scene while also working to maintain the natural integrity of the landscape. One of the primary conflicts in the area is between National Creek and the historic buildings of Kennecott (Figure 13). A dam placed on National Creek to support water needs during the historic mining operations failed in the 1990s, allowing years of rock and soil that had collected behind the dam to enter the creek downstream, producing an aggrading system of channel instability. The unconsolidated material will continue to erode, impacting WRST's cultural resources in the immediate area, until equilibrium is established between sediment size, sediment load, stream slope and stream discharge. It is likely that the problem will continue to exist until the valley is flushed free of the foreign material (Martin and Long, 1993). WRST staff has requested WRD to look at the issue and assist with recommendations.

Figure 13. Cultural resource impacts from the failed dam on National Creek at Kennecott.

Wetlands Management

The NPS implements a "no net loss of wetlands" policy. Executive Order 11990 directs the NPS: 1) to provide leadership and to take action to minimize the destruction, loss, or degradation of wetlands; 2) to preserve and enhance the natural and beneficial values of wetlands; and 3) to avoid direct or indirect support of new construction in wetlands unless there are no practicable alternatives to such construction and the proposed action includes all practicable measures to minimize harm to wetlands (National Park Service, 1998b).

Director's Order 77-1: *Wetlands Protection* requires the NPS to conduct or obtain wetland inventories within each park unit. Presently, WRST does not have an adequate inventory of wetlands within its boundaries to assist proper NPS planning with respect to management and protection of wetland resources. It is important for the NPS to establish baseline wetland information to assist with separating anthropogenic impacts from natural processes.

The U.S. Army Corps of Engineers (COE) - Alaska District and EPA administer the Clean Water Act Section 404 Permitting Program. Over 80% of all actions subject to Section 404 are authorized by the COE via general permits, which authorize categories of activities to proceed without an individual permit application. General permits allow actions with minimal impacts to proceed with little if any administrative burden. This allows regulators and others to concentrate attention on activities with potential for significant impacts. If an activity does have significant impacts it must undergo a more extensive regulatory review. At this point wetlands are regulated mainly through the 404 process.

The Alaska Department of Environmental Conservation's goal is to provide a more scientific and regionally based, rapid assessment tool, through the Hydrogeomorphic Approach Methodology (HGM). The HGM is a type of functional assessment approach that provides a foundation for assessing hydrology, biogeochemical, plant community, and faunal support/habitat functions of wetlands. The Alaska Draft Interior HGM Guidebook has been prepared. It is a rapid assessment tool that applies to specific geographic regions and classes of wetlands. HGM can help permit specialists suggest alternatives to projects involving wetlands (Alaska Department of Environmental Conservation, 2003). The Alaska Department of Environmental Conservation's wetland program is located in Juneau, Alaska (907.465.5321).

Specific issues in WRST related to wetlands management include ORV travel within WRST. WRST has 188 mechanized trails covering 622 miles. Most of these trails occur in communities that are likely to be classified as wetlands. ORV's can damage fragile wetland habitat, unfortunately WRST currently has minimal data to scientifically fully evaluate wetland impacts. Executive Order 11644 requires the designation of ORV trails and areas based on the protection of natural resources. Executive Order 11989 requires Federal agencies to close areas to ORV use when the activity is causing or will cause adverse affects on soils, vegetation, wildlife, wildlife habitat, cultural and historic resources.

WRST will need to expand park infrastructure to accommodate staff and visitor needs (park housing and other facilities). Many of these building sites will be located in wetlands, which are almost impossible to avoid at the lower elevations of WRST, requiring compliance as defined by Executive Order 11990.

The U.S. Fish & Wildlife Service (USFWS) has developed National Wetlands Inventory (NWI) maps for portions of Alaska, including the coast of WRST (U.S. Fish and Wildlife Service, 2003). Wetlands have been mapped for 30 of the 117 USGS quads that cover WRST. WRST has prioritized wetland mapping of the remaining 87 maps. A proposal has been prepared (*Project Statement: WRST 80394*), dividing wetlands mapping of 46 quads in WRST into three phases. Phase I include wetlands mapping for 17 quads along roads and trails (nine along Nabesna and McCarthy roads and eight along trails). An additional 17 quads would be mapped under Phase II (13 along trails and four covering significant native selected lands). Phase III would include wetlands mapping for ten quads with significant private lands and two coastal quads with the potential for increased use and access. The U.S. Fish and Wildlife Service would conduct the mapping under a 50:50 cost-share agreement as described in the "Interagency Agreement between the USFWS and the National Park Service for Cooperation in the Development of Wetland Inventory Maps", using the standard NWI photo-interpretation. Aerial photography available through the Alaska High Altitude Program would be the primary data source.

Spill Contingency Planning

There are many fuel tanks scattered throughout WRST's remote areas to meet the NPS and private landowner's operational needs. These tanks represent potential contamination hazards to aquatic resources, including important water supplies. For example, a primary concern at McCarthy voiced in 1993 was the potential for fuel spills at the airstrip to enter the ground water system and threaten McCarthy's drinking water supply. Clear Creek (Figure 14) is the source of water presently used by the residents of McCarthy. The creek is fed from a shallow aquifer of unconsolidated glacial outwash (Hecht and LaChapelle, 1994).

Figure 14. Clear Creek at McCarthy.

Pollution threats are also posed by the Trans-Alaska oil pipeline (TAPS) located west of the park along the Copper River. The U.S. Geological Survey assisted with evaluating the route selected for TAPS, investigating possible hydrologic hazards and potential impacts to water resources (Childers, 1971). Stream channel erosion was a primary concern for TAPS. Two basic channel erosion problems identified by the U.S. Geological Survey are: 1) erosion that could be severe enough to cause pipeline rupture and oil spillage, and 2) erosion that could cause water quality degradation through siltation of streams. It was speculated that erosion that could endanger the pipeline would probably result from major floods, from the cumulative movement of channels over a period of years, from scour in large alluvial floodplains, and possibly from flow around and under ice or frozen streambeds. Erosion that would cause water quality degradation through siltation would be most likely in small streams with watersheds containing fine-grained erodable soils (Childers, 1971). Several channel erosion survey sites were established by the U.S. Geological Survey along the TAPS route. Although outside of the park, the pipeline crosses four major rivers that drain into the Copper River, which forms the park's western boundary. Oil spilling from a pipeline failure could drain into the Copper River, impacting aquatic resources in WRST. It should be noted that the U.S. Department of the Interior BLM is part of the Joint Pipeline Office (JPO) for TAPS (Rice, pers. comm., 2003).

Transportation of fuel oil to a logging camp just south of the park boundary in Icy Bay is another pollution threat. A spill during transportation or storage could impact WRST's coastal resources.

Proposed offshore oil and gas leasing and development increases the risk of an oil spill polluting the park's 125-mile coastline. Federal offshore oil and gas leases were offered for sale in 1990, but received no expressions of interest. The state of Alaska has also proposed leasing about 350,000 acres in Icy Bay and nearby coastal areas. There is no site-specific information available on beach conditions or resources involved to serve as a baseline if the coast is impacted by a spill. Most NPS inventories to date have focused on public use sites, commercial fishing and guiding facilities, and gross observations of wildlife (National Park Service, 1998a).

The NPS is severely limited in qualified personnel, spill response equipment, and baseline natural resource information to effectively respond to and evaluate impacts from petroleum spills in WRST. Emergency response to a major spill (i.e., *Exxon Valdez Oil Spill of 1989*) requires expertise and field equipment that extends beyond the capabilities of the NPS. There is an interagency spill response plan in place, *The Alaska Federal/State Preparedness Plan for Response to Oil and Hazardous Substance Discharges/Releases* (*Alaska Unified Plan)*. Volume 1 of the *Unified Plan* was completed in 1994 and has been updated twice since then. The primary response agencies are the U.S. Coast Guard, the U.S. EPA, and the Alaska Department of Environmental Conservation. The state of Alaska is divided into 10 subareas. A detailed plan exists for each of these subareas, which is Volume 2 of the *Unified Plan*. WRST spans three subareas, *Prince William Sound Subarea Plan*, *Southeast Alaska Subarea Plan*, and *Interior Alaska Subarea Plan*. Copies of the *Alaska Unified Plan* and appropriate subarea plans were distributed to each NPS Superintendent in Alaska. These NPS Alaska regional response plans are all dated 1988 and need to be updated. Both the *Alaska Unified Plan* and the *Subarea Plans* incorporate NPS participation (Rice, pers. comm., 2003).

Park-specific plans are also required (i.e., Spill Prevention Control and Countermeasure Plan (SPCC Plan)) to address specific NPS facilities and hazardous waste management (i.e, fuel tank compliance, hazardous material storage and disposal compliance, etc.). Currently, WRST does not have a SPCC Plan in place. Information on spill prevention and emergency response is located on the Alaska Department of Environmental Conservation's website (http://www.state.ak.us/local/akpages/ENV.CONSERV/disap/prep/home.htm).

Water Rights

There are many competing water uses in Alaska. Mining, oil and gas, and fishing industries are the three largest competitors. Tourism and water exports are emerging industries that may produce more conflicts. Developments on, within, or adjacent to WRST could draw the NPS into conflicts over water rights. Although the headwaters of all the major drainages that flow through the park originate within park boundaries, inholdings within the park are areas where future conflicts may arise. Perfection of NPS water rights, particularly for instream flows, will provide permanent resource protection against future development and competing uses in and near WRST.

The NPS can hold three different types of water rights in Alaska: state appropriative water rights, state instream flow reservations, or federal reserved water rights. According to the Alaska water rights database, the NPS currently holds five state appropriative water rights, four for surface water and one for subsurface water, in the vicinity of the town of McCarthy within WRST.

State Appropriative Water Rights

A state appropriative water right is a legal right to use surface or ground water under the Alaska Water Use Act (AS 46.15). A state appropriative water right allows a specific amount of water from a specific water source, such as a river or aquifer, to be diverted, impounded, or withdrawn for a specific use. Alaska water law is based on the Prior Appropriation doctrine. The Prior Appropriation or Prior Rights doctrine recognizes a right to the use of water based upon "first in time, first in right" meaning that water rights are given priority based upon the date when water was first put to beneficial use. In Alaska, beneficial uses include but are not limited to domestic, agricultural, irrigation, industrial, manufacturing, fish and shellfish processing, navigation and transportation, mining, power, public, sanitary, fish and wildlife, recreational uses, and maintenance of water quality. An appropriative water right is a property right and may be bought and sold. Four of the five state appropriative water rights currently held by Wrangell-Saint Elias were originally owned by the Consolidated Wrangell mining operation.

Reservations of Water for Instream Use

Private individuals, organizations, and government agencies may apply for a reservation of water for instream use under Alaska state law. A reservation of water for instream use is a water right that protects specific instream water uses, such as 1) protection of fish and wildlife habitat, migration and propagation, 2) recreation and park purposes, 3) navigation and transportation, 4) sanitary and water quality purposes (AS 46.15.145). Instream flow includes the amount, timing and duration of water in streams and rivers, natural lakes, wetlands, and riparian zones. The state may issue a certificate for a reservation of water for instream use if they find that: 1) the rights of prior appropriators will not be affected, 2) the applicant has demonstrated that a need exists, 3) there is unappropriated water in the stream or body of water sufficient for the reservation, and 4) the proposed reservation is in the public interest. The state must review each certificate issued at least once every 10 years, and may revoke or modify the certificate if it is considered in the best interest of the state. Alaska is encouraging the NPS and other federal agencies to secure instream flow water rights through this reservation process in lieu of federal reserved water rights.

Reserved Water Rights

The Federal reserved water rights doctrine is rooted in the Supreme Court decision in Winters v. United States (1908) and has evolved through litigation. The courts have held that when public lands are set aside by the federal government for a particular purpose such as a park, wildlife refuge or military base, sufficient water to accomplish the purposes of the reservation are also set aside. Depending upon the purposes of the reservation, federal reserved water rights may include water for consumptive uses, such as domestic and irrigation, or non-consumptive uses such as instream flow. The rights vest as of the date that the land was reserved, whether or not the water has actually been put to use, and are superior to the rights of those who appropriate water after the reservation date.

The quantification and prioritization of federal reserved water rights are undertaken through court action. The court action can be in the form of a general adjudication in which all water rights in a drainage basin or aquifer system are determined, or as specific cases in which a few competing claims are brought to court for determination. These specific cases only resolve disputes between the parties to the action, and do not address priorities for all water uses within a drainage or watershed.

The McCarren Amendment (43 U.S.C. 666) provides the mechanism that allows the federal government to be joined as a defendant in a state adjudication process. Under this type of proceeding, consent is given to join the United States as a defendant in any suit for the adjudication of rights to the use of water or for the administration of such rights, where the United States is in the process of acquiring federal water rights by appropriation under State law.

Once adjudicated, the federal reserved water rights of the United States are recognized in the state priority system along with any other appropriators. In general, once the United States is joined in an adjudication, that is the only opportunity to assert a claim for reserved water rights. Unless legally absent from the proceedings, failure to assert a claim may result in forfeiture of any reserved water rights. No active administrative or judicial adjudications have been initiated by Alaska in the vicinity of WRST.

The objective of the Department of Interior's water rights program in Alaska is to protect water rights for lands managed by the department. Agencies cannot consumptively use water in Alaska without a water right and must file applications for existing and future diversions and depletions. Instream flow uses will continue but are not protected until the NPS files for either a state reservation for instream flow or federal reserved water right in the appropriate forum (administrative/judicial adjudication). Without a perfected water right, the NPS is at risk of having future uses impact flow regimes and resource values.

Current data for quantifying instream flow water rights at Wrangell-Saint Elias are insufficient. Alaska has no statutory criteria on data requirements to support an application for a reservation of water for instream use under state law. However, Alaska does encourage agencies to use the Tennant Method (Tennant 1972, 1976) for quantifying instream flow requirements. This method suggests five years of stream flow data to quantify water rights.

Claims for federal reserved water rights for instream flows are factually and legally intensive and are primarily guided by the standard that instream flows will be the minimum amount necessary to support the primary purpose of the reservation. Flow data and water-related resource studies are necessary to support federal reserved water right claims. Due to the data intensive nature of determining instream flow needs, the NPS should prioritize data collection efforts, including stream gage installation, and initiate studies as funding becomes available.

The Kennecott-McCarthy area contains the largest number of year-round and seasonal residents who live within WRST. It is also the primary visitor destination. Traditionally, area residents and park visitors have used surface water resources to meet their personal and commercial needs. With an increasing visitor use and a growing summer resident population, greater demands are being place on water resources in the area. WRST acquired the surface rights of the "Kennecott property" in 1998 and the subsurface mineral rights in 1999, which includes 3097 acres of patented mining claims. The area was subdivided prior to acquisition and approximately 100 tracts within the subdivision remain in private ownership. Activities on these private lands include; year-round individual households, summer residences, bed and breakfast, and commercial lodge operations. All uses withdraw water from mountain streams, principally National and Bonanza Creeks. Increasing demand on these surface waters is likely.

WRST management is concerned about unknown threats to water resources in this heavily used area. High quality surface water resources are necessary to support wildlife and botanical communities, insure compatibility with the cultural and natural landscapes and provide for visitor related services, including drinking water. The NPS has not determined nor asserted its federal reserved water right in the Kennecott area. Current water rights for the Kennecott area are presented in Appendix C. With the increasing demands on water resources in the area, WRST has developed a proposal to quantify the amount of water present in National Creek and nearby drainages, and to identify water uses that are necessary to meet park purposes. The recommended tasks in this proposal include:

1. Determine how much water is available and how much has already been appropriated. Kennecott Mining Company originally owned water rights that have been transferred to area residents to appropriate water from National, Bonanza, Jumbo, and Sweet creeks. A detailed water right records search is necessary to document how much water is currently appropriated.
2. Quantify the average daily discharge and range of discharge during periods of stream flow. This will require installing a staff gage and making discharge measurement to produce a stage-discharge data set (rating curve). A rating curve is being prepared for Bonanza Creek (Figure 15). The rating curve is part of an assessment process for consideration of the creek as an energy source to generate electricity for park operational needs.
3. Quantify how much water is currently withdrawn from National, Bonanza, Jumbo and Sweet creeks by local residents and commercial operations. This will be accomplished by interviewing users and obtaining information on current water consumption.
4. Identify the uses for which water is currently (and in the future) needed for park purposes, including both instream flow needs and consumptive uses.

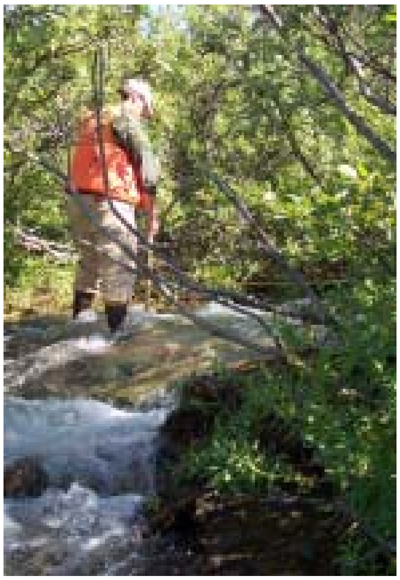

Figure 15. WRST staff recording Bonanza Creek discharge, August 2002.

WRST should develop a prioritized plan for addressing water rights/instream flow data needs in the park. Because water rights determinations will be very costly, this plan may be best accomplished as part of an NPS state-wide plan.

Coordination

Today, multi-agency coordination is essential in all Alaskan park units to effectively monitor and manage the natural resources. Unfortunately at WRST, it is difficult to establish long-term coordination relationships with other agencies. One reason is because Alaska is so large that attention cannot be directed to every watershed in the State due to limited resources. Another reason is that WRST, along with other undeveloped areas in Alaska, lacks the time-sensitive water resource issues or human-induced impacts, which typically drive information-gathering projects.

Coordination by the NPS and Alaska Department of Natural Resources Division of Land and Water Management, Alaska Department of Fish and Game Habitat Division, and Alaska Department of Environmental Conservation is requested for any action taken inside or adjacent to WRST that may relate to: control of turbidity; ground and surface water quality; waste disposal; waste treatment facilities; and withdrawals from, discharges to, or manipulation of stream flow (State of Alaska, 1984).

Cooperation with Canadian officials of the Kluane National Park and Game Sanctuary in coordinating policies, on the ground management, and provision of interpretive and other visitor services is very important (U.S. Department of the Interior, 1974).

Matters of joint concern between the U.S. Forest Service and the NPS include minerals and wildlife management, coastal management (i.e., flooding from advancing Hubbard Glacier) scenic landscape management, forest fire protection, insect and disease control, road and airfield construction, outdoor recreation administration, historic preservation, off-road vehicular use, residential and commercial land use controls, and information and interpretive facilities and services (U.S. Department of the Interior, 1974).

The Alaska Watershed Monitoring and Assessment Project (AWMAP) is a statewide water quality monitoring project involving local, state, and federal agencies; industry; schools; University of Alaska; and other entities conducting water quality monitoring. The AWMAP objectives include (Alaska Department of Environmental Conservation, 1996):

1. Develop a network of individuals interested in and/or involved in the collection of environmental data.
2. Maintain current information on existing monitoring stations and programs in Alaska.
3. Develop a list of environmental indices (biological, chemical and physical) for short- and long-term monitoring that will allow for the assessment of water quality contaminants in Alaska.

4. Coordinate reporting of existing data and receipt of future data from existing monitoring stations in Alaska.
5. Develop a common set of criteria against which information will be evaluated.
6. Develop recommendations annually for locations and types of additional monitoring stations required to meet the overall objectives of monitoring water quality in Alaska's diverse environments.
7. Issue alternate year reports to the Section 305(b) reporting process on status of Alaska's Watershed Monitoring and Assessment Network.

Since 1991, the U.S. Environmental Protection Agency has been promoting the Watershed Protection Approach as a framework for meeting the Nation's remaining water resource challenges (Barbour et. al., 1999). In 1995, the Alaska Department of Environmental Conservation and the U.S. Environmental Protection Agency sponsored the formation of a workgroup to develop a statewide approach for improved watershed management. The workgroup's objective is to create a process that could satisfy many of the regulatory requirements of the Federal Clean Water Act. These include producing Total Maximum Daily Loads (TMDLs) on a watershed basis, coordinating wastewater discharge permits within a watershed, and preparing a comprehensive list of impaired water bodies throughout the State (Alaska Department of Environmental Conservation, 1997). It is important for the NPS to be actively involved in these and other similar efforts to effectively voice their natural resource needs and contribute to the information databases. The Alaska Department of Environmental Conservation has expressed an interest in coordinating with NPS units in Alaska on water resource issues (Decker pers. comm., 1999).

The Interagency Hydrology Committee for Alaska (IHCA) is an organization of technical specialists working at the Federal, State and local levels, who coordinate the collection and implementation of water resources related data throughout the State of Alaska. The IHCA meets twice a year to coordinate multi-agency issues and exchange information. Additional information on the IHCA can be found at http://www-water-ak.usgs.gov/ihca. A Geographic Information System (GIS) for Alaska lands and waters is currently being developed by the Alaska Geographic Data Committee, a joint Federal and State effort (U.S. Department of the Interior, 1998).

The NPS and the Alaska Department of Fish and Game developed a master Memorandum of Understanding (MOU) in 1982 that focuses on fish and wildlife management at WRST. The MOU recognizes that the Alaska Department of Fish and Game and the Boards are mandated the authority and responsibility to manage, control and regulate subsistence, commercial and recreational uses of fish and wildlife in WRST, in a manner consistent with ANILCA (State of Alaska, 1984).

There is a MOU for management of the McCarthy Road and adjacent public lands. Participating agencies are the Alaska Department of Transportation and Public Facilities and Public Facilities, Alaska Department of Natural Resources, Alaska Department of Fish and Game, Federal Highways Administration, Ahtna, Inc., and the NPS. The agreement is intended to provide a framework for land use actions that could impact the

McCarthy Road and adjacent public lands. This is an important forum for discussing matters of mutual interest to the parties (National Park Service, 1986).

The Bureau of Land Management supplies the fire suppression forces for all NPS lands in Alaska. The Bureau of Land Management is subsequently subcontracted with the Alaska Department of Natural Resources to provide suppression forces for the southern section of the state. WRST lands receive suppression support from both agencies under the guidance of interagency fire management plans (National Park Service, 1998a).

Although tidelands, submerged lands, and shorelands adjoining WRST are not under federal jurisdiction, they are important to the resources on adjoining park/preserve lands. The NPS will work cooperatively with the state regarding tidelands, submerged lands, and shorelands. Specifically, WRST will encourage the state to prepare management plans for the tidelands, submerged lands, and shorelands in Icy Bay, adjacent to Malaspina forelands, and in Yakutat Bay (National Park Service, 1986).

RESOURCES MANAGEMENT STAFFING

The WRST Natural/Cultural Resource Management Division staff is presented in Figure 16, which includes both permanent and seasonal positions. Currently WRST is divided into four distinct districts that include the Headquarters (Copper Center, AK), Nabesna, Chitina and Yakutat areas of the park (National Park Service, 2001b). The infrastructure for accomplishing water resource management goals is limited and spread throughout this 13 million acre NPS unit. Due to the lack of adequate park staff, many of the positions must serve multiple disciplines at WRST. For example, the park geologist handles the numerous water quality and stream morphology issues at WRST associated with mining, glaciers and roadways.

The Chief of Resource Management reports directly to WRST's Superintendent and is responsible for the park's natural resource management program, geographic information system and environmental compliance, along with the cultural resource program at the park.

Meeting the current natural resource objectives requires funding and human resources that greatly exceed WRST's current Natural Resources program. Partnerships have helped to alleviate some of the inadequate natural resource support. Many of the park projects that directly or indirectly relate to water resources have been summarized in the preceding sections of this report.

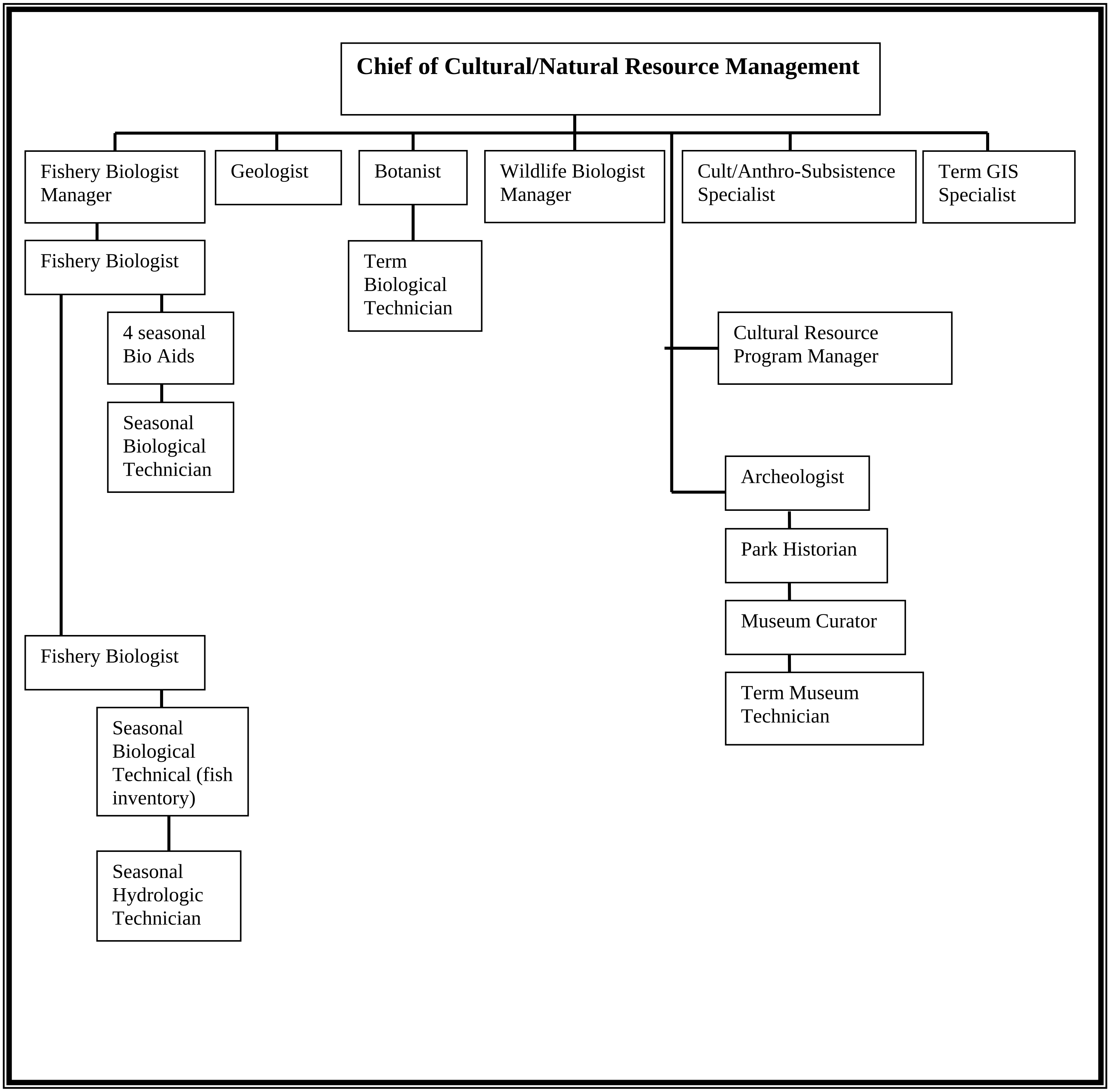

Figure 16. Wrangell-St. Elias National Park and Preserve, Natural/Cultural Resources Program: Organization and Structure

CONSIDERATIONS FOR FUTURE ACTION

The water-related issues and natural resource data presented in this report are supported through regional and local research and monitoring efforts. Identification of available water resource information has also contributed toward exposing the "data gaps", which translates to natural resource needs for WRST. Specific issues and considerations for future actions presented in this report are listed below:

❖ <u>Baseline Inventory and Monitoring</u>

- Continue to support NPS Water Resources Division, providing water quality data collected at WRST, for inclusion in the Baseline *Water Quality Inventory and Analysis* report for WRST.
- Conduct an inventory of WRST's water resources that meet or exceed servicewide standards for Level 1 water resource and water quality inventories. After BLM has completed the "data cleanup", build from the U.S. Geological Survey's National Hydrography Dataset (NHD) (1:100,000 scale) to develop higher resolution products that meet WRST's needs for surface water features.
- Develop a GIS water quality data layer that identifies WRST sites where water quality data exists, with complementary tables that cross-references the sites with the existing water quality datasets.
- Continue and expand the U.S. Geological Survey's small streams network, stream gaging stations/discharge, and stream profile cross-sections, where warranted.
- Establish river gaging stations closer to major glaciers in WRST to better evaluate influences from glaciers on stream flows, and integrate in studies of glacier snow, ice and water balance.
- Continue to work with the Central Alaska Inventory and Monitoring Network (Maggie MacCluskie (Network Coordinator) and Nancy Deschu (NPS-Alaska System Support Office)) to design and implement a regional water quality monitoring program.
- Acquire additional staff qualified to collect data and develop and implement a method to process this data that results in quantifying land use trends and anthropogenic pressures.
- Specific subsistence management activities to be continued or implemented include population and harvest monitoring studies, determination of the eligibility dates of rural residents, administration of backcountry access permits, and limitations on subsistence activities, if necessary, and review of park programs for compliance.
- Support sampling efforts by NPS Air Resources Division (Western Airborne Contaminants Assessment Project) to evaluate long-range transport of airborne contaminants.

❖ <u>Climate Change and Influences on Water Resources</u>

- Conduct investigations of climate and glacier interactions by establishing a network of a few carefully-selected study glaciers and remote weather stations. A transect extending from the coast to the interior has been identified by WRST that includes the Bering Glacier, Bagley Icefield, Tana Glacier, Kennicott Glacier and Nabesna Glacier for conduction of research and monitoring. The Bagley Icefield should have the highest priority for monitoring climate, since this is where the largest expanse of glaciers occur.
- Ground truth information near glacier equilibrium lines in support of current research in remote sensing.
- Identify and sample trees buried and preserved by tephra deposits and old growth stands, which can provide a source of paleoclimate data.
- Evaluate why small lakes and ponds in WRST no longer contain water or have reduced in size since the 1950's including; 1) measuring change in surface area, 2) classification of water bodies, 3) core a few lakes in the different classes, 4) identify which waterbodies are changing the most, 5) develop a plan to broaden the classification of these waterbodies and the effects of species populations dependent on these small lakes and ponds.

❖ <u>Fisheries</u>

- Assist with the completion of fisheries surveys and research within the Yukon/Tana watershed.
- Continue existing work to understand the effect of natural fluctuations in water quality and productivity in Tanada Lake on adult sockeye salmon returns.
- Establish a natural and healthy range for escapement of two sockeye salmon stocks that spawn in Tanada Creek in WRST.
- Develop a Fisheries Management Plan for WRST.

❖ <u>Non-Federal Lands</u>

- Determine customary and traditional means and use of access points and routes as they relate to the temporal and spatial use of subsistence resources.
- Develop management prescriptions that minimize and mitigate ATV impacts to designated trails and water resources.
- Improve access to Batzulnetas for cultural traditions, concentrating on the more preferred eastern route. Restrict vehicles such as trucks and vans.
- Inventory water resources information (i.e., wetlands mapping, stream morphological data) along access roads, including McCarthy Road and Nabesna Road, as needed.
- Work cooperatively with the State of Alaska Department of Transportation to develop a McCarthy and Nabesna Road Plan. Develop strategies for mining of material for road repair.
- Continue assistance with private landowner to realign and construct a new roadbed outside the floodplain of Jack Creek.

- Assist with the defining sensitive recharge areas for Clear Creek and alternate water supplies at McCarthy and establish wellhead protection areas, as appropriate.
- Maintain, and modify as warranted, existing structures that address erosion and aggradation/flooding problems at McCarthy, protecting developed stream banks along McCarthy Creek.
- Monitor permitted stream bank stabilization by private landowner along Chathenda Creek at Chisana.
- Monitor the permitted stream diversion by private landowner at Inlet Creek and evaluate possibilities of structure relocation, acquisition, and land exchange.

❖ Navigability

- Work with the NPS Regional Office to identify and manage navigable waters in WRST. This is a very complex issue that warrants more attention in the Phase II report.

❖ Hydrologic Hazards

- There are six major river systems that originate within WRST: Copper, Chitina, White, Bremner, Nabesna, and Chisana rivers. Where park infrastructure is present or planned or an NPS-supported action occurs, floodplain delineations may be necessary in the future to ensure compliance with the floodplain Executive Order and Directors Order.
- Resurvey the 1995 cross-sections of the two branches of the Kennicott River at McCarthy on a scheduled frequency to calculate changes in channel/floodplain parameters and evaluate the resulting change in flood hazard for the area.
- Continue to monitor lake stage at Hidden Creek Lake to aid in prediction of timing and relative magnitude of annual outburst floods.
- Continue participation with the interagency team (U.S. Forest Service, U.S. Geological Survey, and National Park Service) to provide ongoing monitoring of the advancing Hubbard Glacier and associated flooding impacts to Russell Fjord.
- Build from the assessments conducted around McCarthy by Jones and Glass (1993) and identify other areas in WRST susceptible to landslides and debris-flow hazards.
- Educate staff and visitors on potential hazards associated with seasonal flooding, lake outburst floods, landslides, and snow avalanches.

❖ Coastal Management

- Inventory and monitor coastal resources. This information is critical toward evaluating the efficiency and effectiveness of any spill abatement efforts.

❖ Mining

- Monitor approved mining operations in WRST and local influences on water resources.
- Build from the 1994-1997 Geochemical Study (Eppinger et al., 2000) and further characterize metal contents in waters, soils, sediments and vegetation surrounding the mined mineral deposits and mineral deposits that have not been extracted. Select sampling of waters during high-flow events, when possible.
- Remediate physical mining impacts to streams and associated riparian areas, as appropriate, to re-establish natural equilibrium of stream morphology and improve water quality.
- Educate staff and visitors on potential hazards associated with contaminates from areas that have been mined or include high concentration of mineral deposits.

❖ <u>Recreation Management</u>

- Build from the 1995-1997 ATV Tail Impact Assessment and Mitigation Project in WRST to develop best management practices for ATV use and trail construction.
- Evaluate current ATV trails through the NEPA process and determine solutions to mitigate use on each trail.
- Evaluate human waste impacts at Copper, Ptarmigan and Tanada lakes due to the high recreational use.
- Evaluate the effects of stock use on water quality, soils, and plant communities.
- Expand existing or create new disposal facilities to meet the increasing visitor use.
- Work with NPS-Water Resources Division to develop management strategies for National Creek aggradation impacts on Kennecott historical structures.

❖ <u>Wetlands Management</u>

- Continue work with the U.S. Fish & Wildlife Service (50:50 cost share Interagency Agreement) to map wetlands for 56 quadrangles in WRST.
- Collect wetland data to evaluate impacts to wetlands (i.e., ATV impacts, road impacts).
- Use the Alaska Department of Environmental Conservation's Hydrogeomorphic Approach Methodology (HGM), which can help permit specialists suggest alternatives to projects involving wetlands.

❖ <u>Spill Contingency Planning</u>

- WRST should continue to work with the interagency team on spill contingency planning and emergency response procedures following the *Alaska Unified Plan* and the *Prince William Subarea Plan*, *Southeast Alaska Subarea Plan*, and *Interior Alaska Subarea Plan*.

- Develop a park-specific Spill Prevention Control and Countermeasure Plan (SPCC Plan) to address specific WRST facilities and hazardous waste management (i.e., fuel tank compliance, hazardous material storage and disposal compliance, etc.).

- Water Rights

  - Inventory the current water rights in WRST.
  - Collect discharge, water quality, biological, and recreational data to justify instream water rights. Evaluate these data to determine minimum flow requirements to provide instream flow protection. The Tennant method (Tennant 1972, 1976) has been selected by the State as the primary method for quantifying instream flow requirements.
  - WRST should quantitatively describe the portion of the water supply that is needed for park purposes.
  - Work with WRD-Water Rights Branch to determine and assert WRST's federal reserved water right in the Kennecott area. Build from WRST's proposal to quantify the amount of water present in National Creek and nearby drainages for determining the federal reserved water right.
  - Develop a prioritized plan for addressing water rights/instream flow data needs in WRST. Because water rights determinations will be very costly, this plan may be best accomplished as part of an NPS State-wide plan.

- Coordination

  - Continue to participate in the Alaska Department of Environmental Conservation and U.S. Environmental Protections Agency's state-wide effort, to improve watershed management. Initiate cooperative efforts, supported by the Clean Water Act funding, that address high-priority water-related issues.
  - Monitor efforts by the Interagency Hydrology Committee for Alaska (IHCA) for exposure to available water-related data and to coordinate with other federal, state, and local agencies concerned with WRST's water resources.
  - Maintain and develop new and existing partnerships, including the USGS - Water Resources Division (discharge and water quality monitoring), USGS – Biological Resources Division (salmon population and migration studies), University of Alaska – Fairbanks (water quality assessment), Alaska Department of Fish and Game (fish management). Bureau of Land Management (fire management), McCarthy Road and Nabesna Road Interagency Teams (road management), U.S. Forest Service (recreational use, Hubbard Glacier impacts, fire management), Alaska Department of Natural Resources (water resources management), and Kluane National Park and Game Sanctuary (coordinating policies and park management).

The political and environmental complexity of the park's issues elevates the need to expand upon the information contained in this scoping report by producing a second complementary report. The second report would build from this Water Resources Scoping Report by further developing the water-related issues, including recommended actions (project statements) that address the high-priority issues. These project statements define the specific problem(s) and recommended action(s), including a representative budget that can compete for future internal and external funding calls. This second phase effort should begin with a scoping workshop, inviting appropriate NPS staff and regional watershed stakeholders to participate. The workshop objectives are to identify additional information related to WRST's water resources, expand on the issues captured in the Water Resources Scoping Report, identifying new ones, if warranted, and to have participants prioritize the issues. This effort will help strengthen existing partnerships and encourages other stakeholders to participate with the NPS during and after the second report is complete. Many of the issues presented in this report extend beyond NPS boundaries; thus, it is important to recognize the fact that multi-agency communication and coordination are essential to successfully manage WRST's water resources.

The park is encouraged to place a high priority in seeking funds, both internally and externally, to expand its resource management program, and to develop the Phase II report. Expansion of the park's Resource Management Division with qualified staff is a critical component to a successful process. The two complementary reports will provide only minimal contributions to a park if there is minimal Resource Management staff and discipline-specific expertise to drive the recommendations. Until this Phase II report is prepared for WRST, components of this scoping report should be used in the development of time-sensitive management strategies and actions relating to water resource issues.

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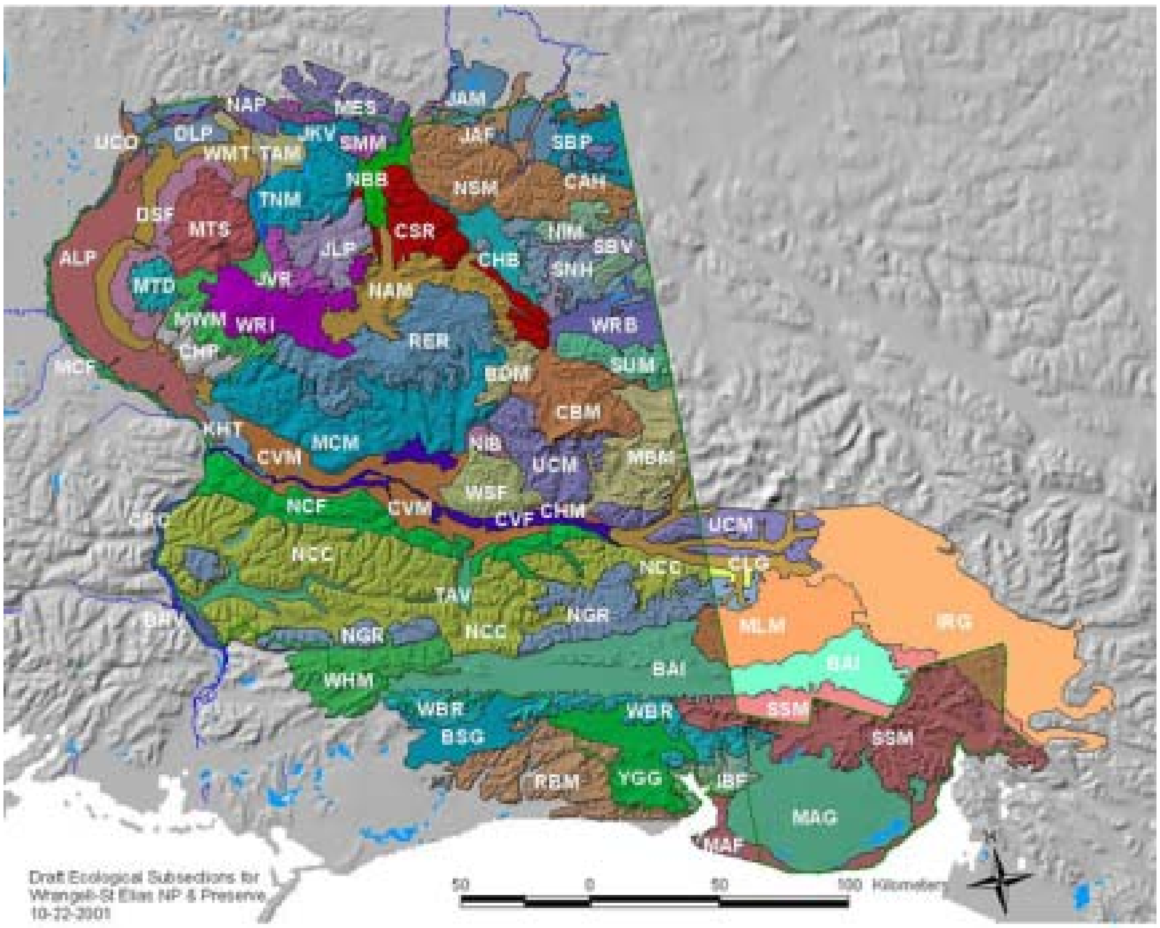
Appendix A. Map of Ecological Subsections of Wrangell-St. Elias National Park and Preserve (National Park Service, 2001a).



Appendix B. Summary of Water Quality Parameters for Nabesna, Nizina, Kennicott and Chisana (National Park Service, 1990a).

Summary of Water Quality Parameters for Streams in the Nabesna Study Area

Location	**CABIN CREEK** *Downstream of mine tailings*	**JACK CREEK** *Upstream of Cabin Creek*
Date	9/5/86	9/5/86
Flow (cfs)	1.4	80.2
Suspended solids (mg/l)	22.0	2.2
Turbidity (NTU)	25.0	1.3
pH	6.5	-
Conductivity (umhos)	620.0	345.0
Sulfate (mg/L)	150.0	-
Cyanide (mg/L)	<0.01	-
Arsenic (mg/L)	<0.005	<0.005
Cadmium (mg/L)	<0.01	<0.01
Chromium (mg/L)	<0.05	<0.05
Copper (mg/L)	<0.05	<0.05
Iron (mg/L)	3.3	0.09
Lead (mg/L)	<0.05	<0.05
Manganese (mg/L)	0.21	0.01
Mercury (mg/L)	<0.10	<0.10
Zinc (mg/L)	0.17	<0.05

Note: Metal data are ICP total recoverable values, averages over 6 replicates.

Summary of Water Quality Parameters for Streams in the Nizina Study Area

Location	**CHITITU CREEK** *Downstream of disturbed area*	**REX CREEK** *Upstream of disturbed area*	**REX CREEK** *Downstream of disturbed area*	**DAN CREEK** *Downstream of disturbed area*
Date	7/24/86	7/24/86	7/31/86	7/25/86
Flow (cfs)	293.0	159.0	30.0	-
Suspended solids (mg/L)	120.0	1.6	7.4	1,246.0
Turbidity (NTU)	808.0	18.5	8.3	724.0
pH	-	-	-	-
Conductivity (umhos)	180.0	110.0	205.0	-
Alkalinity (mg/L)	59.0	24.2	47.0	-
Hardness (mg/L)	82.0	42.0	89.0	-
Arsenic (mg/L)	0.009	<0.005	<0.005	.02
Cadmium (mg/L)	<0.01	<0.01	<0.001	<0.01
Chromium (mg/L)	<0.05	<0.05	<0.05	<0.05
Copper (mg/L)	0.057	<0.05	<0.05	0.05
Iron (mg/L)	46.0	0.48	0.63	25.0
Lead (mg/L)	<0.05	<0.05	<0.05	-
Manganese (mg/L)	0.85	<0.01	0.01	0.4
Mercury (mg/L)	<0.1	<0.1	<0.1	<0.1
Zinc (mg/L)	0.15	<0.05	<0.05	0.07

Note: Metal data are ICP total recoverable values, averages over 6 replicates.

Summary of Water Quality Parameters for Streams in the Kennicott Study Area

Location	**NIKOLAI CREEK**. *Downstream of disturbed area*	**BONANZA CREEK.** *Upstream of disturbed area*	**NATIONAL CREEK.** *Downstream of disturbed area*	**McCARTHY CREEK** *Downstream of disturbed area.*
Date	7/22/86	7/28/86	7/28/86	7/30/86
Flow (cfs)	11.8	15.5	11.3	193.0
Suspended solids (mg/L)	1.8	1.4	1.6	113.0
Turbidity (NTU)	3.5	0.26	1.8	110.0
pH	-	-	-	-
Conductivity (umhos)	180.0	134.0	110.0	250.0
Alkalinity (mg/L)	-	61.0	49.0	169.0
Hardness (mg/L)	91.0	69.0	46.0	124.0
Arsenic (mg/L)	<0.005	<0.005	<0.005	0.009
Cadmium (mg/L)	<0.01	<0.01	<0.01	<0.01
Chromium (mg/L)	<0.05	<0.05	<0.05	<0.05
Copper (mg/L)	<0.05	<0.05	<0.05	0.06
Iron (mg/L)	0.35	0.09	0.1	7.4
Lead (mg/L)	<0.05	<0.05	<0.05	<0.05
Manganese (mg/L)	0.02	<0.01	<0.01	0.14
Mercury (mg/L)	<0.1	<0.1	<0.1	<0.1
Zinc (mg/L)	2.08	<0.05	<0.05	0.09
PCB (mg/L)	-	-	<0.1	<0.1

Note: Metal data are ICP total recoverable values, averages over 6 replicates.

Summary of Water Quality Parameters for Streams in the Chisana Study Area

Location	**BIG ELDORADO** *Upstream of disturbed area*	**BIG ELDORADO** *Downstream of disturbed area*	**GOLD RUN CREEK** *Upstream of disturbed area*	**LITTLE ELDORADO** *Upstream of disturbed area*	**LITTLE ELDORADO** *Downstream of disturbed area*	**SKOOKUM CREEK** *Upstream of disturbed area*	**BONANZA CREEK** *Upstream of disturbed area*	**BONANZA CREEK** *Downstream of disturbed area*	**CHATHENDA CREEK** *Downstream of Bonanza Creek*	**CHAVOLDA CREEK** *Downstream of Glacier Creek*
Date	6/24/87	6/25/87	9/25/87	6/23/87	6/22/87	6/23/87	6/24/87	6/24/87	6/18/87	6/17/87
Flow (cfs)	8.5	7.8	1.0	2.9	10.9	2.1	2.5	21.3	115.0	51.3
Suspended solids (mg/l)	<2.0	3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	-
Turbidity (NTU)	1.0	1.8	3.2	3.0	9.2	0.8	1.6	4.45	22.5	1.2
pH	7.0	7.3	6.6	8.5	8.3	7.6	8.0	7.8	7.5	-
Conductivity (umhos)	31.0	65.0	29.0	240.0	185.0	40.0	240.0	170.0	172.0	187.0
Alkalinity (mg/L)	60.0	23.0	8.0	97.0	69.0	50.0	183.0	73.0	77.0	71.0
Hardness (mg/L)	136.0	45.0	41.0	95.0	88.0	19.0	165.0	78.0	86.0	112.0
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-
Cadmium (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	-
Chromium (mg/L)	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	-	-
Copper (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
Iron (mg/L)	<0.03	<0.03	<0.03	<0.03	<0.03	<0.069	<0.03	<0.06	-	-
Lead (mg/L)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	-	-
Manganese (mg/L)	<0.003	<0.003	<0.003	0.006	<0.003	<0.003	<0.003	<0.006	-	-
Zinc (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-

Note: Metal data are ICP total recoverable values, averages over 6 replicates.

Appendix C. Water Rights at Kennecott.

AKDNR Number	C. Owner	Drainage	Water Right	Date	Status	Purpose	Volume	SUP	Surveyed	Note	Originated
LAS 11265	NPS-WRST	Bonanza	Acq: Kennecott	May-64	Cert to Appropriate	Placer Mining	2.0 cfs				Consolidated Wrangell
LAS 11266	NPS-WRST	Bonanza	Acq: Kennecott	May-64	Cert to Appropriate	Placer Mining	3.0 cfs				Consolidated Wrangell
	Brewster & Malik	Bonanza	Water line		Waterline				yes-acq		None
	Charlie O'Neil	Bonanza	Water line						yes		None
	Sam Gregory	Bonanza	Water line		Water line	Single Dwelling			no		None
	NPS-WRST	Bonanza	Water Rights - Kennecott								Kennecott Corporation
ADL 46282	NPS-WRST	Jumbo	Acq: Kennecott	May-64	Cert to Appropriate	Placer Mining	100gpm				Consolidated Wrangell
ADL 46282	NPS-WRST	Jumbo	Acq: Kennecott	May-64	Cert to Appropriate	Single Dwelling	500gpm				Consolidated Wrangell
LAS 22101	Larry Hoare	Jumbo	Water line	Jun-98	Water line	Single Dwelling		SUP	yes-acq		
	NPS-WRST	Jumbo	Water Rights - Kennecott								Kennecott Corporation
ADL 1983	Jurick	National	Private	Jun-98	Cert to Appropriate	Single Dwelling	500 gpd				Jurick
ADL 20264	Kennicott Gl. Lodge	National	Private	Apr-96	Cert to Appropriate	Commercial Use	3750gpd		Asbuilt		Kennicott Glacier Lodge
ADL 21354	Jurick	National	Private	Dec-98	Cert to Appropriate						Jurick
ADL 46283		National	Lapsed/Abandoned		Lapsed??						
ADL 80402/3	Richards	National	Lapsed/Abandoned	Mar-77	Closed						Richards
LAS 11256		National	Lapsed/Abandoned		Lapsed??			SUP			
LAS 19893		National	Lapsed/Abandoned		Lapsed??						
LAS 23080	NPS-WRST	National	Pending	Apr-00	Application	Public	3300gpd				NPS-WRST
LAS 23287	Doherty	National	Private	Nov-00	Application	Single Dwelling					Doherty
	Mike McCarthy	National	Water line		Water line	Commercial			yes-acq	KGL Asbuilt	None
	Nick Olmsted	National	Water line		Waterline				yes-acq		None
	NPS-WRST	National	Water Rights - Kennecott								Kennecott Corporation
LAS 23829	Mozen	Sweet	Private	Nov-02	Application	Residential	250 gpd				Mozen, Howard
LAS 23831	Mozen	Sweet	Private	Nov-02	Application	Residential (2)	500 gpd				Mozen, Howard
	Ben Shaine	Sweet	Water line		Water line	Single Dwelling			yes-acq		None